SECONDARY STAGE CHEMISTRY

BOOK ONE

FOR CLASS IX

Notes

For

Sindh Textbook Board, Jamshoro.

INTRODUCTION TO CHEMISTRY

DEFINITION:

"The branch of Natural science which deals with the study of composition, properties, structure, changes and the laws governing the changes that occurring inside the matter is called Chemistry."

MATTER:

Anything having mass and occupy space is known as Matter.
There are three commonly known states of matter. According to latest Information there are four states of matter

1. Solid
2. Liquid
3. Gas
4. Plasma (newly discovered fourth state of matter but not known commonly)

LANDMARKS IN THE HISTORY OF CHEMISTRY

THE GREEK PERIOD:

Famous Greek philosophers:
Plato (347-428 B.C)
Aristotle (322-384 B.C)
Democritus (357-460 B.C)

- They introduced the concept of element, atom and chemical reactions.
- They thought that all matter was derived from four elements earth, air, fire and water.
- These elements have properties of their own such as dry, hot, cold and wet.
- According to them, fire was hot and dry, earth was cold and dry, water was cold and wet and air was hot and wet.

The Romans developed the chemical arts still further:

- They improved the metallurgical processes and introduced the enameling of pottery. However, they developed little theoretical knowledge in this regard. Their works were all empirical.

THE MUSLIM PERIOD:

The Muslim period was from 600 to 1600 A.D in the history of chemistry and is known as period of alchemist.
The modern scientific knowledge is based on the contribution of these Muslim scholars.

Jabir-Ibne-Hiyan(721-803 A.D):

He is generally known as the father of alchemy (founder of Chemistry).

- **Achievements:**

i) He invented experimental methods for preparation of Nitric acid, Hydrochloric acid and sulphuric acid.
ii) He discovered white lead.
iii) He also developed methods for the extraction of metals from their ores.
iv) He also developed methods of dyeing clothes.
v) He developed method of distillation.
vi) He also developed many laboratory apparatus.

Al Razi (862-930 A.D):
Al Razi was a physician, chemist (at that time they were known as alchemist) and a philosopher.

- **Achievements:**

i) He was an expert surgeon and was the first to use opium as anesthesia.
ii) He divided the substances into living and non-living origins, which was later adopted by Berzelius, in 1806 to classify chemical compounds on the basis of their origins as organic and inorganic compounds.
iii) Al-Razi prepared ethyl alcohol by the fermentation of sugar.

Al-Beruni(973-1048 A.D):
Contributed a lot in physics, metaphysics, mathematics, geography and history. In the field of chemistry, he determined the densities of different substances.

Ibne-Sina(980-1037):
Ibne-Sina was famous for the contribution in the field of medicines, medicinal chemistry, philosophy, mathematics and astronomy.

DIRECTION OF RESEARCH OF MUSLIM SCIENTISTS:

- These Muslim alchemists were interested more in finding a way to prolong life and to convert base metals like lead, copper into gold but they could not do so.
- Their researches led to the discoveries of many substances and laid the foundation of chemistry. Many important reagents like sulphuric acid, Nitric acid, Hydrosulphyuric acid, Silver nitrate etc were discovered.
- Chemists of that period, however, devoted their energies mainly to the production of drugs for the use of medicines.

THE MODERN PERIOD (FROM 1600 A.D AND ONWARD):

NAME OF SCIENTISTS CONTRIBUTION IN CHEMISTRY:

1. **ROBERT BOYLE (1627-1691):**He is affectionately known as the father of modern chemistry and was the first to put forward the idea that chemistry should be regarded as a systematic investigation of nature with the sole aim of promoting knowledge. As a result, lots of discoveries were made during later years.

2. **J.BLACK (1728-1799):** He made a study of Carbon dioxide.

3. **J.PRIESTLY (1733-1804):** He discovered Oxygen, Sulphur dioxide and Hydrogen chloride.

4. **SCHEELE (1742-1786):** He discovered Chlorine.

5. **CAVENDISH (1731-1810):** He discovered Hydrogen.

6. **LAVOISIOR (1743-1794):** He discovered that oxygen constituted about one fifty of air.

7. **GAY- LUSSAC (1778-1850):** He discovered relationship between volume of given mass of a gas and temperature.

CHEMISTRY AND SOCIETY

SIGNIFICANT REASONS TO STUDY CHEMISTRY (Importance of chemistry):

There are three significant reasons to study chemistry.

1. Chemistry has important practical application in the society. The development of life saving drugs is one and a complete list would touch upon the most areas of modern chemistry.
2. Chemistry is an Intellectual enterprise, a way of explaining our material world.
3. Chemistry figures prominently in other fields, such as in biology in the advancement of medicines.

EXAMPLES OF CHEMICAL SUBSTANCES USED IN DAILY LIFE:

Use of chlorine and fluorine in daily life:

It is used in making poly vinyl chloride (PVC) as plastic pipes. Other chlorine compounds are used as bleaching agent, disinfectants, solvents, pesticides, refrigerants, flame retardant and drugs.

Chlorine: is used in treating water to kill pathogenic (disease causing) organism. In this way the disease like Cholera, Typhoid, Fever and Dysentery are dangerous disease are all eliminated from most of the part of the world.

Fluorine: is used in compounds like sodium fluoro phosphate and NaF (sodium fluoride) in our toothpastes to protect and control tooth decay. It is great advantage of chemistry on the society.

BRANCHES OF CHEMISTRY

1. **PHYSICAL CHEMISTRY:**
   The branch of chemistry which deals with the laws and the principles governing the combination of atoms and molecules in chemical reaction and study of physical properties of matter is called PHYSICAL CHEMISTRY.

2. **ORGANIC CHEMISTRY:**
   The branch of chemistry which deals with the study of Hydrocarbon and their derivatives with the exception of CO2, CO, metal carbonates Bicarbonates and carbides is known as ORGANIC CHEMISTRY.

3. **INORGANIC CHEMISTRY:**
   The branch of chemistry which deals with the study of chemistry of elements and their compounds, generally obtained from non-living organism, i.e. from minerals is known as INORGANIC CHEMISTRY.

4. **ANALYTICAL CHEMISTRY:**
   The branch of chemistry which deals with the study of the methods and techniques involved to determine the kind, quality of various components in a given substance is known as ANALYTICAL CHEMISTRY.

5. **BIOCHEMISTRY:**

The branch of chemistry which deals with the study of compounds chemical reaction involves in living organism i.e. plants and animals and their metabolism in the living body is known as BIOCHEMISTRY.

6. INDUSTRIAL OR APPLIED CHEMISTRY:

The branch of chemistry which deals with the study of different chemical processes involved in the chemical industries for the manufacturing of synthetic products like glass, cement, paper, soda asli, fertilizers, medicines etc. is known as INDUSTRIAL CHEMISTRY.

7. NUCLEAR CHEMISTRY:

The branch of chemistry which deals with the study of changes occurring in the nuclei of atoms, accompanied by the emission of invisible radiations is known as NUCLEAR CHEMISTRY.

8. ENVIORMENTAL CHEMISTRY:

The branch of chemistry which deals with the study of the interaction of chemical materials and their effects on the environment of animals and plants is known as ENVIORMENTAL CHEMISTRY.

9. POLYMERIC CHEMISTRY:

The branch of chemistry which deals with the study of polymerization and the product obtained through the process of polymerization such as plastic, synthetic fibers, paper etc. is known as POLYMERIC CHEMISTRY.

THE SCIENTIFIC APPROACH IN CHEMISTRY

Science has developed through series of discoveries from many years which started off as observed natural phenomenon which had to be explained. This was done by using scientific method in a systematic manner.

SCIENTIFIC METHOD:

There are four main stages of scientific method:
1. Observation.
2. Hypothesis
3. Theory
4. Scientific Law of principle

1. OBSERVATION:

"Observation is a basic tool to elaborate a phenomenon varies from person to person and depends upon person's own skills and elaboration."

Different people observe a phenomenon in different ways. Some of us observe something very critically to extract from it a new point. Observation of a thing is one of the scientific approaches in chemistry.

2. HYPOTHESIS:

"The explanation obtained by the pondering of a scientist after observing a phenomenon which is still on a trial is called Hypothesis."

When a phenomenon is observed, a scientist ponders over it and carries out relevant experiments. He sieves through the data and arrives at apossible explanation for the nature of the phenomenon. This explanation, which is still only a trial is called hypothesis. It may

or may not undergo a change which results further investigations and accumulation of more knowledge or facts.

3. THEORY:

"The Hypothesis which is supported by a large number of different types of observations and experiments given by many scientists is known as Theory."

The scientist conveys his hypothesis to other workers of the same fields for the discussion and for further experimentation. When the hypothesis is supported by a large amount of different types of observation and experiments, then it becomes a theory i.e. scientifically acceptable idea or principle explain a phenomenon. A good theory predicts new facts and unravels new relationship between occurring phenomenon.

4. SCIENTIFIC LAW OR PRINCIPLE:

"A theory which is tested again and again and found to fit the facts and from which valid predictions maybe made is then known as scientific law or principle."

Science cherishes all form of ideas and proposals. Even obsolete (outdated) ideas are kept as reference. It is said that there is no end to knowledge, so development in science too may have no limits.

EXERCISE

1. Fill in the blanks:

i) The early Greeks believed that everything in the universe was made up of four elements Earth, Air, Fire and Water.
ii) Al-Razi divided chemical substances on the basis of their origin as living and non-living.
iii) Organic chemistry is the branch of chemistry which deals with the carbon compounds.
iv) Bio chemistry is the backbone of Medical science.
v) PVC which is a plastic is the short name of Poly Vinyl Chloride.
vi) Oxygen was discovered by J. priestly.
vii) The best disinfectant is Chlorine.
viii) The periodic arrangement was the result of Mendeleev's work.

LAWS OF CHEMICAL COMBINATION

CHEMICAL REACTIONS:
When two or more substances combined together or a single substance changes up to produce one or more substances with entirely different properties, such a change is called chemical reaction.

- $4Fe + 3O_2 \rightarrow 2FeO_3$
- $2MG + O_2 \rightarrow 2MgO$

LAWS OF CHEMICAL COMBINATION:
Chemistry deals with chemical reactions. Chemist had found that these changes are governed by some empirical law known as Laws of Chemical Combinations.

These laws are:
- Law of conservation of mass.
- Law of constant composition OR Law of definite proportions.
- Law of multiple proportions.
- Law of reciprocal proportions.

1. LAWS OF CONSERVATION OF MASS:
Lavoisior in 1785 gave the law of conversation of Mass. This law states that:

"Matter can neither be created nor be destroyed by chemical change."

OR

"in any chemical reaction the initial mass of reacting substance is equal to the final mass of products."

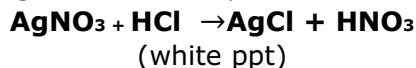
After latest research law can be stated as:

"There is no detectable gain or loss of mass in an ordinary chemical reaction."

PRACTICAL VERIFICATION: (Landolt Experiment)
This law was verified by many experiments performed by H. Landolt. He was a German chemist. His most popular and the simplest experiment is as follows:

Experiment:
He took an H- shaped tube having two limbs 'A' and 'B' as shown in figure. One limb 'A' was filled with $AgNO_3$solution and the other limb was filled with HCl solution. The upper portion of the limbs were sealed to avoid the escaping of any material. Both solutions are colourless. The H-shaped tube was weighed in vertical position to avoid mixing. Then the tube was inverted and shaken to mix the two solutions. Following reaction took place.

$$AgNO_3 + HCl \rightarrow AgCl + HNO_3$$

(white ppt)

Due to formation of AgCl percipitates of white color, the entire tube became white. The reaction was completed by shaking and inverting the tube.

H-shaped tube was weighed again. It was observed that the tube mass of the substances before the reaction was equal to the total mass of the substances after reaction.

CONVERSATION OF MASS TO ENERGY:
Certain radioactive substances like uranium undergo changes of such nature that very small quantity of mass is conventional to energy by thy following equation given by Albert Einstein in 1906.

$$E = mc^2$$

Where "m" is mass of the substance in gm and "c" is the velocity of light in cm/sec **($3x10^2$ cm/sec)**. By putting these values in equation (A) we can calculate the amount of Energy obtained by the conversation of the mass. This change of mass in ordinary experiments is so small that it cannot be detected by ordinary weighing techniques.

FINALLY THE LAW OF CONSERVATION OF MASS:

Law of conservation of mass can be stated as:

"There is no detectable gain or loss of mass in an ordinary chemical reaction."

2. **LAW OF CONSTANT COMPOSITION OR LAW OF DEFINITE PROPORTIONS:**

Statement:

"Different samples of the same compound always contain the same element combined together in the same proportion by mass"

Example:

Water obtained from any source(prepared in laboratory, or obtained from rain, river or water pump), but if it is pure water always contain Hydrogen and Oxygen in the ratio of 1:8 by mass.

H2O
2:16 (Atomic mass of H is 1 and O is 16)
1:8 (parts by mass)

Experimental verification:

Swedish chemist J.J Berzelius performed an experiment to prove this law.

10gm of lead (Pb) was heated with excess of sulphur but only 1.56gm of sulphur combined to give 11.56 gm of PbS.

Again this experiment was repeated by heating 18gm of Pb and 1.56gm of "S", it was observed that 11.56gm of PbS was prepared and 8g of Pb remained unused.

This indicates that Pb and S always combine in the fixed ratio by mass. This is according to the law of constant composition.

3. **LAW OF MULTIPLE PROPORTIONS:**

Statement:

"If two element combined to form more than one compound, the masses of one element that combines with a a fixed mass of the other element are in the ratio of small whole numbers or some multiple of it"

Example:

Carbon and oxygen combine to form two stable compounds CO and CO_2

COMPOUND	MASS OF CARBON (C)	MASS OF OXYGEN (O)	RATIO OF (O)
Carbon monoxide CO	12	16	1
Carbon dioxide CO2	12	32	2

From above chart it is very clear that 12g 'C' combines with 16g of 'O' in CO and 32gm of 'O' in CO2 . Hence the ratio of 'O' is 16:32 or 1:2 which is the simple multiple ratio.

4. LAW OF RECIPROCAL PROPORTIONS:

Statement:

"when two different elements separately combine with the fixed mass of third element the proportions in which they combine with one another shall be either in the simple ratio or some multiple of it."

Example:

'C' , 'H' and 'O' combine separately to form CH_4, H_2O and CO_2

METHANE CH4	MASS OF C-12	MASS OF H-4	RATIO OF H:C 4:12 OR 1:3
Water H2O	Mass of H '2'	Mass of O-16	RATIO OF H:O 2:16 OR 1:8
Carbon dioxide CO2	Mass of C 12	Mass of O-32	RATIO OF C:O 12:32 OR 3:8

From the above chart I is clear that in CH4 1gm H combines with 3 gm of C and in H2O 1gm H combines with 8 gm O. Also in CO2 the ratio of C and O is 3:8 which is according to the law of Reciprocal proportion.

ATOMIC MASS:

" The atomic mass of an element is the average mass of natural mixture of isotopes which is compared to the mass of $1/12^{th}$ part of an atom C-12."

Its unir is a.m.u.

The mass of an atoms depends upon Neutrons and protons present in nucleus

The mas of an atom is so small that it cant be measured by any ordinary weighing instrument.

The mass of Hydrogen atom is **1.6×10^{-24}g** (a very small mass)

C-12 has 6 protons and 6 neutrons, so the mass of C is 12 atomic mass unit(a.m.u).

The mass of C-12 is taken as a standard. Hence (a.m.u is $1/12^{th}$ of the mass of C-12 atom. For example the mass of H is $1/12^{th}$ mass of C-12, so its atomic mass is 1 a.m.u. Most of the elements consists of its isotopes. The average of the mass of isotopes give the atomic mass of the atom.

The atomic mass of O=16, S=32, H=1, Ca=40, Mg=24.

EMPIRICAL FORMULA (E.F) OR SIMPLEST FORMULA:

"The formula that shows the simplest ratio between the atoms of different elements of a compound is called empirical formula."

COMPOUND	MOLECULAR FORMULA	EMPIRICAL FORMULA
Benzene	C_6H_6	CH
Gulocose	$C_6H_{12}O_6$	CH_2O
water	H_2O	H_2O

The empirical formula of Benzene, Gulocose and Hydrogen Peroxide are different from their Molecular Formulae.

Hence for a compound, Empirical and Molecular Formula may be similar or different.

MOLECULAR FORMULA:

"Molecular Formula is the formula which represents a molecule of an element or a compound with exact number of atoms."

Relationship between molecular and empirical formula:

Molecular formula = n x Empirical Formula
OR n = (Molecular Formula)/(Empirical Formula)
Similarly
n = (Molecular Formula mass)/(Empirical Formula mass)

MOLECULAR FORMULA MASS OR MOLECULAR MASS:

"Molecular Formulae Mass of a substance is the sum of the atomic mass of all atoms present in the molecular formula of a substance or molecule."

COMPOUND	MOLECULAR FORMULA	MOLECULAR MASS
Carbon dioxide	CO_2	12+2(16)=12+32=44
Gulocose	$C_6H_{12}0_6$	6(12)+12(1)+6(16)=180
water	H_20	2(1)+16=2+16=18

FORMULA MASS:

"Formula mass of a substance is the sum of the atomic masses of all atoms in a formula unit of the substance"

Explaination:

Some compounds are not available in molecular form. For example NaCl is available in ionic form NaCl, so we can consider its formula mass and not molecular mass.

MOLAR MASS:

"Molar mass of the substance is its relative Atomic mass, Molecular mas or Formula mass expressed in grams."

MOLE:

"The atomic mass, Molecular mass or Formula mass of a substance expressed in grams is known as Mole."

AVOGADRO'S NUMBER (N_A):

"One mole of any substance contains $6.02x10^{23}$ particles (atoms, molecules, ions or formula units). This constant number is called Avogadro's number."

INTERCONVERSION OF MASS AND MOLE:

Number of moles = (Mass of substance in grams)/(Gram Atomic mass OR formula mass)
Mass of substance = Number of moles x Gram Atomic mass or Formula mass

PROBLEM: Calculate the number of moles in 50g of each: (a) Na (b) H_2O

Solution:

Method # 1

Number of moles of Na = ?
Given mass of Na = 50g
Atomic mass of Na = 23 a.m.u

Number of moles of Na = (Mass of Na in grams)/(Gram Atomic mass of Na)
= 50/23

Number of moles of Na = 2.173 moles of Na.

Solution:
Method # 2

Number of moles of H_20= ?
Given mass of H_20 = 50g
Atomic mass of H_20 = 18 a.m.u

Number of moles of H_20 = (Mass of H_20 in grams)/(Gram Atomic mass of H_20)
= 50/18

Number of moles of H_20 = 2.777 moles of H_20.

USE OF AVOGADRO'S NUMBER:

PROBLEM: Calculate the number of Atoms in 10g of Al.

Solution:
Method # 1

According to Avogadro's number.
1 mole of Al = 27g = 6.02×10^{23} atoms.

This shows that.

27g of Al contain 6.02×10^{23} atoms of Al
1g of Al contain 6.02×10^{23}/ 27g
10g of Al contain (6.02×10^{23} x 10) / 27g = **2.23×10^{23} atoms of Al**Answer

Solution:
Method # 2

Number of atoms = (N_A x Mass of substance in grams) / (Gram Atomic mass)
Number of atoms of Al = (6.02×10^{23} x 10g) / 27g
Number of atoms of Al = **2.23×10^{23} atoms of Al** Answer

CHEMICAL REACTION OR CHEMICAL CHANGE:

"A chemical reaction is that change in which the chemical composition of a substance is altered."

During a chemical reaction, the original substances produce one or more new substances.

Examples:

i) Rusting of Iron $4Fe + 3O_2 \rightarrow 2Fe_2O_3$
Iron Oxygen Iron oxide (rust)

ii) Burning of Coal C + $O_2 \rightarrow$ $C0_2$
Carbon OxygenCarbon dioxide

TYPES OF CHEMICAL REACTION:

Chemical reactionis divided into five different types.

i) Decomposition reactions.
ii) Addition reaction (Combination reaction)
iii) Single displacement reaction
iv) Double displacement reaction
v) Combustion reaction

1. DECOMPOSITION REACTIONS:

"Decomposition reactions is that chemical reaction in which a substance is divided into two or more simpler substances."

Example:

$CaCO3(s) \rightarrow CaO(s) + CO2(g)$

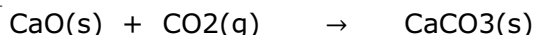
In this reaction Calcium Carbonate on heating is divided into Calcium oxide and Carbon dioxide gas.

2. ADDITION REACTION (Combination Reaction):

"Addition reaction is that reaction in which two or more substances combine to form a single substance."

Addition reaction is the reverse of decomposition reaction.

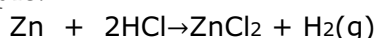
Example:

$CaO(s) + CO2(g) \rightarrow CaCO3(s)$

In this reaction Calcium Oxide and Carbon dioxide are added to give Calcium carbonate.

3. SINGLE DISPLACEMENT REACTION:

"Displacement reaction is that reaction in which one atom or group of atoms of a compound is replaced by another atom or goup of atoms."

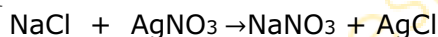
Example:

$Zn + 2HCl \rightarrow ZnCl_2 + H_2(g)$

In this reaction H of HCl is replaced by Zn

4. DOUBLE DISPLACEMENT REACTION:

"In double displacement reaction the two compound exchange their partners so that new compounds are formed."

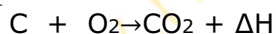
Example:

$NaCl + AgNO_3 \rightarrow NaNO_3 + AgCl$

In the above reaction the exchange of partners takes place.

5. COMBUSTION REACTION:

"In combustion reaction substances react with oxygen (free oxygen or oxygen of air) to produce eat energy and flame."

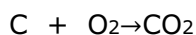
Example:

$C + O_2 \rightarrow CO_2 + \Delta H$

In this reaction carbon is burnt with oxygen to form carbon dioxide along with evolution of heat and flame.

CHEMICAL EQUATION:

"Chemical equation is a method of expressing the chemical reaction in terms of symbols and formulae of the substances involved in the chemical equation."

Example:

$C + O_2 \rightarrow CO_2$

POINTS TO REMEMBER:

1. Reactants are on the left hand side of the reaction and product are on the right hand side of the reaction.
2. Balancing of Equation is done by coefficients.
3. Delta over an arrow indicates that reactant is heated to give product.
4. Catalyst is represented by its symbol written over arrow.

BALANCE CHEMICAL EQUATION:

Balanced chemical equation gives the following information.

i) The nature of reactants and products.

ii) The relative number of each reactants and products.

RULES OF BALANCE CHEMICAL EQUATION:

i) Write the given formulae for all reactants on the left hand side and the formulae of products on right hand side of an equation.
ii) Mention the number of atoms on both sides of chemical equation
iii) If the number of atoms appear more on one side than the other, balance the equation by inspection method. For this purpose multiply the formula by coefficient so as to make the number of atoms, same on both sides of an equation.
iv) The covalent molecule of hydrogen, oxygen, nitrogen and chlorine exist as diatomic molecule e.g H_2, N_2, O_2 and Cl_2, rather than isolated atoms hence we must write them as such in chemical equation.
v) Finally, check the balanced equation, to be sure that the number and kind of atoms are the same on both sides of the equation.

BALANCE THE CHEMICAL EQUATION:

Example:

1. $KClO_3 \rightarrow KCl + O_2$

Write down the number of atoms on each side.

Reactants →	**Products**
K (1)	K (1)
Cl (1)	Cl (1)
O (3)	O (2)

It is clear that K and Cl elements have same number of atoms on both sides of equation, but the Oxygen atoms are not balanced so we place 2 on left hand side and 3 on right hand side (cross multiply) to balance the Oxygen atoms.

$2KClO_3 \rightarrow KCl + 3O_2$

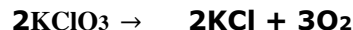
Reactants →	**Products**
K (2)	K (1)
Cl (1)	Cl (1)
O (6)	O (6)

Now we simply balance K by placing 2 in front of KCl.

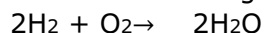
$2KClO_3 \rightarrow 2KCl + 3O_2$

Reactants →	**Products**
K (2)	K (2)
Cl (1)	Cl (1)
O (6)	O (6)

The Equation is now balanced.

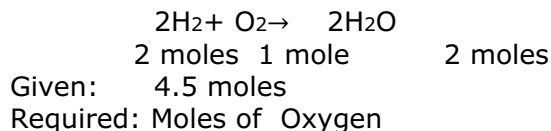
$\mathbf{2KClO_3 \rightarrow 2KCl + 3O_2}$

CONCEPT OF MOLE RATIO TO CALCULATE THE AMOUNT OF REACTANTS:

Q. Consider the following reaction.

$2H_2 + O_2 \rightarrow 2H_2O$

i) How many moles of Oxygen are needed to react with 4.5 moles of Hydrogen.
ii) How many grams of Hydrogen will completely react with 100g of Oxygen to form water?

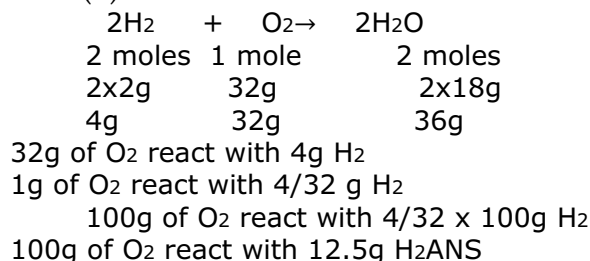
ATOMIC MASSES : H=1 and O= 16

Solution(i):

$2H_2 + O_2 \rightarrow 2H_2O$
2 moles 1 mole 2 moles
Given: 4.5 moles
Required: Moles of Oxygen

2 moles of H_2 react with 1 mole of O_2
1 mole H_2 react with ½ mole of O_2
4.5 moles H_2 react with ½ x 4.25 moles of O_2
4.5 moles H_2 reacts with 2.25 moles of O_2ANS.

Solution(ii):

$2H_2 + O_2 \rightarrow 2H_2O$
2 moles 1 mole 2 moles
2x2g 32g 2x18g
4g 32g 36g

32g of O_2 react with 4g H_2
1g of O_2 react with 4/32 g H_2
100g of O_2 react with 4/32 x 100g H_2
100g of O_2 react with 12.5g H_2ANS

RESULT:

i) Number of moles of Oxygen = 2.25 moles
ii) 100 g of Oxygen require 12.5g of H_2

EXERCISE

i) 18 grams of H2O contains **6.02×10^{23}** molecules.
ii) A change which alters the composition of a substance is called **chemical change.**
iii) A reaction in which a chemical substance breaks down to form two or more simpler substance is called **decomposition reaction**.
iv) The reaction of NaCl with AgNO3 is given as:
NaCl + AgNO3 → NaNO3 + AgCl
Is the reaction of a type **double displacement**
v) When metals react with acid or water then produce **H_2** gas.
vi) **Addition** is the reaction in which two or more substances combine together to form a single substance.
vii) A reaction in which a substance burns in oxygen to produce heat and flame is called **combustion reaction**.
viii) **Chemical equation** is the short hand method to describing chemical reaction.
ix) The reaction $Zn + 2HCl \rightarrow ZnCl_2 + H_2 (g)$ is the **single replacement reaction**.

ATOMIC STRUCTURE

ATOM:

Definition:

"Atom is a complex organization consisting of sub-atomic particles called Electrons, Protons and Neutrons."

Dalton's Atomic Theory:

This theory was given by British school teacher of chemistry.
This theory is based on the following points.

i. All elements are made up of small indivisible, indestructible particles called atoms.
ii. All atoms of a given element, are identical in all respects, having same size, mass and chemical properties. But the atoms of one element differ from the atoms of other element.
iii. Compounds are formed when atoms of more than one element combine in a simple whole number ratio.
iv. A chemical reaction is a rearrangement of atoms, but atoms themselves are not changed, this means that atoms are neither created nor destroyed in chemical reactions.

Defects in Dalton's Atomic Theory:

i. According to Dalton's Atomic Theory, atoms of elements are indivisible and that no particle smaller than atom existed but the research confirmed that each atom consists of very small particles in the term of Electrons, Protons, Neutrons.
ii. According to Dalton's Atomic Theory, different atoms of same element are identical in all aspects. But this is not true.
The discovery of isotopes proved that atoms (isotopes) of same element differ in mass i.e. C^12 and C^13 are two isotopes of Carbon. C^12 has atomic mass 12 a.m.u whereas C^13 has atomic mass 13 a.m.u. This difference of Neutrons in the two isotopes.

Modern Atomic Theory:

i. Matter is composed of very tiny particles which pisses all the properties of an element called Atom.
ii. Atom is a complex organization consisting of sub-atomic particles called Electrons, Protons and Neutrons.
iii. a) Atoms of an element are identical in size, shape and chemical properties but they may differ in their masses. Such atoms of an element are called Isotopes.
b) The atoms of one element are different from the atoms of other elements in all respect but the atomic masses of two or more elements may be same.
iv. Compounds are formed when atoms of more than one element combine in a simple whole number ratio.
v. A chemical reaction is a rearrangement of atoms, but atoms themselves are not changed, this means that atoms are neither created nor destroyed in chemical reactions.

Fundamental particles of an Atom:

Each atom consist of three subatomic particles called Electrons, Proton and Neutron. These subatomic particles are also called Fundamental particles.

DISCOVERY OF ELECTRONS OR CATHODE DISCHARGE TUBE EXPERIMENT:

Electron is a fundamental particle of each atom having negative charge. This negative particle was discovered by a British physicist J.J Thomson.

Experiment:

This experiment consists of a glass tube of thick walls. The tube is fitted with two metal electrodes connected with negative and positive terminals of a high voltage battery. These plates are called Cathode and Anode respectively. This large tube consists of a small outlet tube connected with Vacuum pump.

First of all this tube is filled with a gas at ordinary pressure. Now with the help of a vacuum pump the gas is evacuated such that the pressure of the gas inside the tube is reduced Anode). This high voltage is slowly increased till a change in the tube is observed between the electrodes. Streaks of bluish lights having direction from cathode to anode are observed, It appears that these rays travels in straight lines from Cathode to Anode and a glow is observed on the tube toward Anode side where the rays strike.

To study the nature of charge (positive or negative) of the particle, these particles ere passed through electric and magnetic field in the form of rays. It was observed that the particles travelling toward Anode were deviated from their path toward the positive plate of the magnetic field, so it is a clear indication that these particles are negatively changed called Electrons.

Same experiment was performed by changing the gas in the tube. It was observed that the nature of these particles remained same.

Same experiment was performed by changing the metal of electrodes, it was observed that the nature of particles remained same.

Important point to remember:

The negatively charged particles in the form of Cathode rays were not obtained from Cathode plate but these were originated by the discharge of gas particles between the two plates Cathode and Anode due to opposite charge. Since the direction was from Cathode to Anode these were called Cathode rays (actually are electrons).

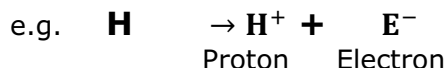
Properties of Cathode Rays (Electrons):

i. If an opaque object is placed in the path of cathode rays a shadow was observed which indicates that these particles travel in straight lines.
ii. If a light paddle wheel is placed in the path of Cathode rays the wheel rotates which indicates that Cathode rays are material particles. The mass of each particle was found equal to 1/1837 of the lightest Hydrogen atom (Isotope of Hydrogen having atomic mass equal to 1 a.m.u).
iii. When these Cathode rays are allowed to strike glass material or some other materials, it is observed that these materials produce fluorescence (glow).
iv. When these are deflected toward positive plate which indicates that these are negatively charged particles.
v. The e/m ratio (charge/mass) ratio of Cathode particles is $\mathbf{1.7588x10^{8} c/g}$ (coulomb/gram). The e/m ratio of electrons is also same. The Cathode particle of any other gas also carry the same e/m ratio.
vi. Since these Cathode particles are material particles and can produce mechanical pressure and are moving with certain velocity, so poses Kinetic energy.

DISCOVERY OF PROTONS:

Each atom is electrically neutral (having no charge), but each atom contains electrons inside it and those electrons are negatively charged particles, it means that positively charged particles are also present in each atom. These particles are called protons and each proton carry same quantity of positive charge as quantity of negative charge on each electron. Proton is also fundamental particle of all atoms.

Hydrogen (H) consists of one electron and one proton.

e.g. **H** $\rightarrow H^{+}$ **+** E^{-}
Proton Electron

Experiment:

Goldstein a German physicist in 1886 performed an experiment to show the presence of material particles which are positive in nature.

He performed the same gas discharge tube experiment with the only difference was that the cathode was perforated.

It was observed that positive material particles crossed these perforations were collected behind the Cathode plate.

In 1897 J.J Thomson also confirmed the existence of these positively charged particles called protons. He also studied the properties of protons.

Properties of Positive rays:

i. These rays travel in straight line in the direction from Anode to Cathode.
ii. When these rays were passed through electric field, it was observed that the particles were deflected toward negative plate, which indicates that these are positively charged particles.
iii. The e/m ratio of positive particle is much smaller than that of electrons.

Discovery of Neutrons:

In 1832 the British physicist James Chadwick discovered a third fundamental particle of atom with the help of artificial radioactivity. This particle is neutral in nature, having mass nearly equal to the mass of a proton.

Properties of Electron, Proton and Neutron:

ELECTRON	PROTON	NEUTRON
1) Charge: The charge of Electron is negative. 2) Quantity of charge: $1.602x10^{-19}$Coulomb Or $4.8x10^{-10}$ e.s.u. 3) Mass: Mass of electron is : $9.109390x10^{-31}\ kg$	4) Charge: The charge of Proton is positive. 5) Quantity of charge: $1.602x10^{-19}$Coulomb Or $4.8x10^{-10}\ e.s.u.$ 6) Mass: Mass of electron is : $1.672623x10^{-27}\ kg$	7) Charge: Neutron is neutral. 8) Quantity of charge: No charge. 9) Mass: Mass of electron is : $9.109390x10^{-31}\ kg$

Important points to remember:

i. The charge of Electron is simply considered as $1.602x10^{-19}$Coulombs.
ii. Similarly the charge of proton is simply considered as$1.602x10^{-19}$Coulombs.

iii. At some places the charge of Electron is written as $-1.602x10^{-19}$Coulomb. This is just an indication that it is negatively charged with the given value. This negative sign cannot be used for calculation purpose.

iv. Similarly at some places the charge of proton is written as $+1.602x10^{-19}$Coulombs to show magnitude of positive charge.

v. The mass of electron is 1/1836 part of the mass of proton. Similarly proton is 1836 times heavier than electron.

RADIOACTIVITY:

A phenomenon related to spontaneous disintegration of nucleus of an atom and emission of invisible radiations from the nucleus of an atom is called radioactivity.

Radioactive Substance:

"The substance which emit radiations spontaneously is called radioactive substance."

Examples of Radioactive substance:

Uranium (U), Thorium (Th) and Polonium (Po) are common examples of radioactive elements.

Type of Rays (α, β and γ Rays):

In 1902 a British Physicist Ernest Rutherford performed an experiment to study the nature of radioactive rays.
A radioactive material was placed in the cavity of a thick Lead block.
Radiations coming out of the cavity were passed through two plates of strong electric field. It was observed that these radiations split into three directions.

Positive charged particles:

i. Were deflected toward negative plate.
ii. These positive charged particles are called Alpha (α) particles.

Negatively charged particles:

i. Were deflected towards positive plate.
ii. These negative charged particles are called Beta (β) particles.

Neutral rays:

i. Were not deflected in any direction showing that these are neutral (having no charge).
ii. These rays are called Gamma (γ) rays. These are not particle in nature.

Rutherford Atomic Model:

In 1911 Lord Rutherford successfully performed an experiment to study the structure of an atom.
Rutherford bombarded Alpha particle on a very thin Gold metal foil. He found the most of alpha particles passed through it without any deflection. Some of Alpha particles were deflected at large angles. Very few Alpha particles bounced back as shown in figure.
On the basis of this experiment Rutherford gave the following conclusions.

i. Since most of the 'α' particles passed un-deflected, so most of the portion of atom is empty.
ii. Very few 'α' particles bounced back, so the middle portion is the hardest portion of the atom and the entire positive charge of the atom is concentrated in that portion called nucleus.

Conclusions:

On the basis of the above experiment Rutherford concluded that nucleus of the atom of an element is positively charged and that nearly the entire mass of the atom is concentrated in that portion. This nucleus is located in the middle part of the atom.

Since atom as a whole is neutral (having a no charge) so there must be negative charge outside the nucleus. This negative charge is in the form of electrons revolving round the nucleus and the mass of electron is negligibly small as compared to the mass of the nucleus.

Nucleus not only consist of positively charged protons but it also contain neutral particles called Neutrons. The mass of Neutron is nearly equal to the mass of Proton.

Electrons revolve round the nucleus in various orbits called shells or energy levels.

Weaknesses or Defects in Rutherford's Atomic Model:

i. According to classical electromagnetic theory a charged particle during its motion dissipates energy. If we apply this theory on electrons having negative charge it seems that during continuous revolving motion of electrons the energy is dissipated and due to loss of energy the electron must fall into the nucleus. This is not true.

ii. Since the electron revolves continuously, the energy dissipated must be continuous, so a continuous spectrum must be formed. But in actual practice line spectrums are obtained.

Bohr's Atomic Model:

In 1913 a Danish physicist gave a theory to solve the questions raised against Rutherford's atomic model.

Bohr's atomic model is based on the following points.

i. Electron is negatively charged particle but during its revolution it does not dissipate energy. So it will not fall in to the nucleus.

ii. When electron gains returns back in to its original energy level but it does not remain there and finally returns back to its original energy level. During downward jump of lines is called the line spectrum. The quantum energy is directly proportional to the frequency of radiation.

i.e. $\Delta E = E2 - E1 = h v$

where h = Planks constant.

V = Frequency of the radiation.

Atomic Number (Z):

"Atomic number is the number of protons in the nucleus of an atom."

- Atomic number is generally denoted by (Z).
- We know that the number of protons inside the nucleus of a neutral atom is equal to the total number of electrons outside the nucleus.
- All atoms are identified by their atomic numbers.
- No two elements can have same atomic number.

Consider the example of Carbon and Nitrogen:

Atomic number of Carbon is 6, but Atomic number of nitrogen is 7, so the properties of Carbon and Nitrogen are different. Because the number of protons of Carbon is 6 so the number of electrons is also 6. On the other hand the number of protons of Nitrogen is 7 so the number of electrons of Nitrogen is 7.

Note: Chemical properties of elements depend upon number of electrons of neutral atom.

Mass Number (A):

"Mass number is the total sum of protons and neutrons in the nucleus of an atom."

- All atoms (except ordinary Hydrogen atom) consist of both protons and neutrons inside its nucleus.
- Mass number (A) = Number of protons (Z) + Number of neutrons (N).
- A = Z + N.
- Number of neutrons = A – Z.

Consider the example of Sodium (Na):

Atomic number of Na = 11, and the mass number of Na = 23.
Therefore number of protons inside nucleus = 11.
And number of electrons outside nucleus = 11.
Number of Neutrons = A – Z.
= 23 – 11.
= 12.

ISOTOPES:

"Atoms of an element having same number of proton but different number of neutrons are called Isotopes."

OR

"Isotopes are the atoms of same element having same atomic number but different atomic masses."

Consider the isotopes of chlorine (i) Cl-35 and (ii) Cl-37.
In Cl-35 the atomic number is 35, so the number of neutrons = 35-17 = 18.
In Cl-37 the atomic number is 17, so this chlorine also contains 17 protons and 17 electrons.
In Cl-37 the mass number is 37 so the number of Neutrons = 37 -17 = 20.

Note:

- Different isotopes of an element contain same number of electrons and same number of protons but different number of neutrons.
- Since chemical properties of an element depend upon the number of electrons in elements therefore two isotopes of an element have same properties.

OTHER EXAMPLE OF ISOTOPES

Isotopes of Hydrogen:

There are three isotopes of Hydrogen.

i. Protium.
ii. Deuterium.
iii. Tritium.

- Protium contains 1 electrons, 1 proton and 1-1 = 0 means no neutron.
- Deuterium contains 1 electron, 1 proton and 2-1 = 1 neutrons.
- Tritium contains 1 electron, 1 proton and 3-1 = 2 neutrons.
- All these three isotopes have same chemical properties because they contain same number of electrons, but the difference is of mass due to difference in number of neutrons.

Applications of Isotopes:

- Usually isotopes are radioactive in nature except stable isotopes. So the radioactive isotopes are used as tracer (to trace many hidden things). Therefore a radio isotope helps in diagnosis of so many diseases.
- From a radioactive isotope radiations are emitted, which help in the cure of many diseases like cancer, in which these radiations are used for radiotherapy purpose.

ELECTRONIC CONFIGURATIONS:

Electron in an atom around revolve round its nucleus. These electrons revolve in different circular orbits called energy levels or shells.

The distribution of electrons on different energy levels is called electronic configuration.

These shells are designated as K, L, M, N, O and P orbits.
Each shell is also given a number 'n' as 1,2,3,4,5, and 6 respectively.
On the basis of these numbers we can calculate the number of maximum electrons in these shells, with the help of a formula 2n^2.
First 'K' shell contain 2n^2 = 2 x 1^2 = 2 electrons (maximum).
Second 'L' shell contain 2n^2 = 2 x 2^2 = 8 electrons (maximum).
Third 'M' shell contain 2n^2 = 2 x 3^2 = 18 electrons (maximum).

EXERCISE

1. Fill in the blanks.
   - i. **Rutherford atomic** model says that atom consists of small. Dense, positively charged nucleus which is surrounded by electrons, revolving around it.
   - ii. Atomic number of sodium is **11**.
   - iii. Number of proton + number of neutron is the **Mass Number** of an element.
   - iv. **Isotopes** are the atoms of the same elements, having same number of protons but different number of neutrons.
   - v. The number of isotopes of Hydrogen is **three.**
   - vi. **Atomic Number** is thenumber of positive charges in the nucleus of an atom.
   - vii. A – Z indicates the number of **Neutrons** in the nucleus of an atom.
   - viii. Z = number of protons in the nucleus of an atom number of **electrons** in a neutral atom.

THE PERIODIC TABLE

Up till now 110 elements have been discovered out of these 92 are naturally occurring elements and the rest have been artificially prepared in the laboratories by nuclear reactions.

HISTORICAL DEVELOPMENT OF THE PERIODIC TABLE:

Periodic table was given after several stages of developments. These stages are discussed below.

AL-RAZI'S CLASSIFICATION:

i. Al-Razi classified the elements in to metals, non-metals and their derivatives.
ii. The elements were divided in to metals and non-metals based upon the difference in their physical and chemical properties.

DOBEREINER'S TRIADS:

In 1829, a German chemist Johan Wolfgang Dobereiner found out the relationship between atomic masses and properties of elements for the classification of elements. He arranged similar elements in to groups of three. These families of three elements are known as DOBEREINER'S TRIADS.

LAW OR RULE OF DOBEREINER'S TRIADS:

"Central atom of each set of triad had an atomic mass almost equal to the arithmetical mean of the atomic masses of other two elements."

Dobereiner noticed that when the three elements in a triad were arranged in order of relative atomic masses, the relative atomic mass of the middle element was very close to the average of the other two elements.

For Example:

The approximate relative atomic mass of the Chlorine and Iodine are 35.5 and 126.9 respectively. The average mass is 81.2 which is very close to the atomic mass of the middle element Br. i.e. 79.9.

$$(35.5+126.9)/2=81.2$$

Similarly the relative atomic mass of Sodium 23.0 is the average of the relative atomic masses of Lithium (6.9) and Potassium (39.1).

i.e. $(6.9+39.1)/2=23.0$

NEWLAND'S OCTAVE:

"In 1864 John Newland, and English chemist, reported his law of octaves. He arranged the elements in order of increasing atomic masses.

LAW OF OCTAVES:

"If the elements are arranged in ascending order of their atomic masses, then every eight element starting from any point approximately has similar properties as of the first, like the eighth note in the octave of music."

Element	Li	Be	B	C	N	O	F
Atomic Mass	7	9	11	12	14	16	19
Element	Na	Mg	Al	Si	P	S	Cl
Atomic Mass	23	24	27	28	31	32	35.5
Element	K	Ca					
Atomic Mass	39	40					

From the above chart it is very clear that the properties of Li, Na and K are similar because these elements fall in eighth of the series. Similarly Be, Mg and Ca are similar in properties.

DISCREPANCIES OF NEWLAND'S OCTAVE:

i. 'H' was not included in this sequence.
ii. This law was not applicable for large number of elements.

PERIODICITY:

"Repetition of similar properties after a regular interval or period is called PERIODICITY"

LOTHER MEYER'S CLASSIFICATION:

In December 1869 a German scientist Julius Luther Meyer arranged 56 elements which were discovered till then in a periodic table.
Luther Meyer's classification based on atomic masses. He observed the relationship between physical properties (like volume) of the elements and their atomic masses therefore he arranged the elements on the basis of their atomic masses in nine vertical columns or groups from I to IX.
The periodicity of physical properties becomes clear by comparing the atomic volumes of various elements.

ATOMIC VOLUME:

"ATOMIC VOLUME is the space occupied by gram atomic weight (1 mole) of atoms of an element in solid or liquid state Number of atoms in a gram atom of elements is constant i.e. $6.02 x 10^{23}$.
Luther Meyer calculated the volumes of eight elements.

Atomic volume = Gram atomic weight / Density

He plotted a graph between Atomic Volume of elements against their increasing atomic masses. The curve obtained consists of sharp peaks and broad minima.
He observed that the elements with similar positions on the curve. For instance, the highly reactive alkali metals (Li, Na, K, Rb, and Ca) occupy the peaks showing that these elements have largest atomic volumes.
The regular spacing of the highest point confirms the idea of periodicity, suggested by Newland.

MENDELEEV'S PERIODIC TABLE:

In 1869, the Russian chemist, Dimitri Mendeleev, produced new ideas to support the theories, which Newlands, had suggested five years earlier. He arranged the elements I increasing order of their atomic masses.

THE PERIODIC LAW:

According to Mendeleev,

"The properties of element are the periodic function of their Atomic Weight."

Mendeleev arranged the elements in 12 horizontal rows called periods and 8 vertical columns called groups. The eight groups were further divided in to sub-groups.

SALIENT FEATURES OF THE TABLE:

i. It has eight columns called groups and twelve horizontal rows called periods.
ii. Elements in each vertical columns have similar properties.
iii. Vacant spaces for the elements not discovered until then. He proposed their names as EKa-Boron, EKa-Aluminum and EKa-Silicon.
iv. The group number indicated the highest valence that can be attained by elements of that group.

ADVANTAGES OF MENDELEEV'S PERIODC TABLE:

i. It helped in systematic study of elements. For example the study of sodium helps to predict the properties of other alkali metals as potassium, rubidium, and cesium. It forcefully proved the concept of periodicity.
ii. Prediction of new elements was made possible. Mendeleev predicted the physical and chemical properties of some element like EKa-Boron, EKa-Aluminum and EKa-Silicon. It helped in their discovery. Their properties were remarkably same as predicted by Mendeleev. They have been named as scandium (Eka-Boron), Gallium (EKa-Aluminum) and Germanium (EKa-Silicon).
iii. Mendeleev's periodic table helped in correcting many doubtful atomic masses.
iv. There was a regular gradation in the physical and chemical properties in a sub-group.
v. The group number of an element indicate the highest valence state it can attain.
vi. Mendeleev left many spaces vacant in his periodic table for unknown elements and also predicted their properties.

Discrepancies in the Mendeleev's Periodic Table:

i. There are three pairs of elements i.e. elements of higher atomic masses placed before elements of lower masses. i.e.
   a) Argon (40) placed before Potassium (39).
   b) Cobalt (59.9) placed before Nickel (58.6).
   c) Tellurium (127.5) placed before Iodine (126.9).
ii. This table does not give any indication about the position of Isotopes.
iii. Dissimilar elements placed in same group i.e. Alkali metals (Li, Na, K etc.) were placed with coinage metals (Cu, Ag, Au).
iv. Mendeleev's table does not give an idea of structure of atoms.
v. Lanthanides and Actinides have been assigned in same place in the periodic table which goes against periodic law.

vi. The change in the atomic masses of two successive elements is not constant. Hence it is not possible to predict the number of missing elements by knowing the atomic masses of two known elements.

CONCLUSION:

On the basis of the above discussion we can conclude that the classification of the elements on the basis of atomic masses was not correct. In other words, atomic mass is not a fundamental property of the element.

Prediction of New Elements (The Missing Elements):

Mendeleev made some remarkable predictions about the undiscovered elements to fill the gaps in his table. Some examples are given below:

i. Mendeleev predicted the properties of a metallic element to fill the gap below Aluminum and next to Zinc. When Gallium was discovered in 1876. It was found to confirm the almost accuracy of Mendeleev's predictions.
ii. Mendeleev predicted the element he called EKa-Silicon (meaning below silicon) with its actual properties when it was found in 1886 and named Germanium (Ge).

MODERN PERIODIC TABLE:

MODERN PERIODIC LAW:

"Physical and chemical properties of elements are the periodic function of their Atomic numbers."

After the discovery of proton it was found that the properties of elements depend upon number of protons and their electronic configuration (electronic arrangement).

PERIODS:

"The horizontal rows in periodic table are called periods. There are seven periods in the modern periodic table."

1st PERIOD:

The first period consists of two elements. Hydrogen (H) and Helium (He). Hydrogen contains only one proton in its Nucleus, so its atomic no. is 1. In the same manner it contains 1 electron in its orbit due to this resembles to alkali metals which also have 1 electron in their outermost shell.

The next element is Helium. It has 2 electrons in the first shell. The electronic configuration of He is K=2. First shell cannot accommodate more than 2 electrons that is why Helium is placed in VIII or zero group. Helium shows extraordinary stability and inertness due to filled shell.

SECOND AND THIRD PERIOD:

Second and third period are called short periods. There are only eight elements present in these periods. Each element placed in respective group according to their electronic configuration. The elements included in these periods are:

2nd Period:

Li, Be, B, C, N, O and F.

3rd Period:

Na, Mg, Al, Si, P, S, Cl and Ar.

4th PERIOD:

Fourth period is called long period. They include eighteen elements, out of eighteen elements eight are called normal element and the remaining ten are called Transition elements.
Normal elements: K, Ca, Ga, Ge, As, Se, Br and Kr.
Transition elements: Sc, Ti, V, Cr, Mn, Fe, Cn, Ni, Cu and Zn.

5th PERIOD:

The fifth period is called a long period. It consists of eight normal elements and ten transition elements.
Normal elements: Rb, Sr, In, Sn, Sb, Te, I and Xe.
Transition elements: Y, Zr, Nb, Mo, Tc, Ru, Rh, Pd, Ag and Cl.

6th PERIOD:

The sixth period is the longest period and it consists of 32 elements. It consists of 8 normal elements, 10 outer transition and 14 called Lanthanides or Rare Earth Metals.
Normal elements: Cs, Ba, Ti, Pb, Bi, Po, At and Rn.
Outer transition: La, Hf, Ta, W, Re, Os, Ir, Pt, Au and Hg.
Inner transition: Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Ex, Tm, Yb and Lu.

7th PERIOD:

Seventh period is incomplete. It contains two elements as normal elements, ten outer transition element and fourteen inner are called actinides. The actinides are radioactive elements. Some of them have been proposed artificially.
Normal elements: Fr and Ra.
Outer transition: Ac, Unq, Unp, Unh, Uns, Une, Uno and Unu.
Inner transition: Th, Pa, U, Np, Pu, Am, Cm, Bk, Cf, E, Fm, Md and No.

GROUPS:

"The vertical columns in the periodic table are called groups."

Element with similar outer electronic configuration show similar properties and are placed in same group.

Periodic table consists of eight Groups. They are further sub divided in to two sub-groups. Normal elements are kept in "A" group and transition elements in sub group "B",

GROUP I-A THE ALKALI METALS: (LITHIUM FAMILY)

i. The alkali metals, lithium, sodium, potassium, rubidium, cesium and francium are light metals.
ii. They are very reactive chemically and are strongly mono electro positive elements.
iii. Ionization potential decrease gradually downward in the group.
iv. All these metals contain only one electron in their outermost shells.
v. They form ionic bond by the loss of valence electron.
vi. Alkali means "ashes". This is an Arabic word. Compound of these metals were obtained from wood ashes and it is also because they form water and soluble bases (Alkalies).

GROUP II-A THE ALKALINE EARTH METALS:

i. Beryllium, magnesium, calcium, strontium, barium and radium are included in Group IIA the alkaline earth metals.
ii. They are moderately reactive metals, harder and less volatile than the alkali metals.

iii. These elements are found as silicate minerals and their oxides and hydroxides are strongly basic. Therefore these elements are called Alkaline Earth Metals.
iv. They contain two electron in their outer most shell.
v. Metallic characters increase downward in the group.

GROUP III-A THE BORON FAMILY:

i. Boron, aluminum, gallium, indium and thallium are included in this group.
ii. Boron is metalloid, while the other members of this group are metals.
iii. These elements are quite reactive chemically and are highly electropositive.
iv. They have three electrons in their outermost shell.
v. Metallic characters increase downward in the group.
vi. The elements of this group shown tendency to form covalent bond like non-metals due to small size, high charge and large value of ionization potentials.
vii. (Metalloid = Elements which have some properties of metals and some properties of non-metals).

GROUP IV-A CARBON FAMILY:

i. Carbon, silicon, germanium, tin and lead are present in this group.
ii. They show intermediate characteristics.
iii. It is the middle group of periodic table forming the link between the more electropositive. And electronegative elements. Elements of group I and II and more electronegative elements of group V to VII.
iv. They contain same electronic configuration and have four electrons in their outermost shell.
v. Electronegativity decreases from carbon to lead.
vi. Carbon and silicon being more electronegative are non-metals and form covalent bonds only by sharing their four valence electrons.
vii. Tin and lead are electropositive. They are typical metals and form ionic bonds by losing electrons in their valence shell.
viii. Allotropes of C and Sn elements are found in this group.

GROUP V-A THE NITROGEN FAMILY:

i. Nitrogen, phosphorus, arsenic, antimony and bismuth are included in this group. Nitrogen and phosphorous are non-metals. Arsenic and antimony are metalloids and bismuth is weakly metallic.
ii. They have five electrons in their outer most shell and require three electrons to complete their octet.
iii. The tendency of forming covalent bonds decrease from nitrogen to bismuth.
iv. Nitrogen exists as diatomic molecules (N2) and forms number of oxides NO, N2O, NO2, N2O4 and N2O5.
v. Due to small atomic size and large ionization potential, nitrogen has a tendency to accept three electrons to form Nitride N^{-3}.
vi. Bismuth forms ionic bond only and forms "Bi^{3+}".
vii. Phosphorus exists as P4 molecule.
viii. The ionization potential are high, hence nitrogen and phosphorous are distinctly electronegative.
ix. Except nitrogen all exist in more than one allotropic forms. The group displays a remarkable number of allotropes of its member.

Note: (Different forms of an atom having same chemical properties and different physical properties are called Allotropes and the phenomenon related to its called Auotropy).

GROUP VI-A THE OXYGEN FAMILY:

i. Oxygen, sulphur, selenium, tellurium and polonium are the members of group VI-A.
ii. Oxygen and sulphur are non-meals, whereas tellurium and selenium are close to metalloids and basic metallic properties are shown only by polonium.
iii. The metallic character, ionic and basic nature increase from oxygen to polonium.
iv. Oxygen is a gas other elements are solids.
v. They have six electron in their outer most shell.
vi. All the element exhibit property of Allotropy e.g. Ozone O3 and O2.
vii. They form ionic compounds by the gain of two electrons and form covalent by sharing two electrons e.g. H-O-H, H-S-H, O=C=O, Cl-S-S-Cl.
viii. The electro negativity values of these elements are very high and decrease down the group.

GROUP VII-A THE HALOGEN FAMILY:

i. Fluorine, chlorine, bromine, iodine and astatine are included in the Halogen group (Halogen = salt former).
ii. They are very active non-metals and are very much like in their chemical properties.
iii. They contain seven electrons in their outermost shell and require only one electron to attain stability.
iv. They form covalent compounds as well as ionic compounds e.g. NaCl (ionic), HCl (covalent).
v. Halogens are highly electronegative elements and their electronegativity decreases down the group from fluorine to iodine.
vi. Fluorine and chlorine are gases and rest of them are solid elements except bromine which is liquid.
vii. They easily accept an electron to form halide ions.
viii. They all are found as diatomic molecule. They cannot exist in Free State because of their extreme activity.

GROUP VIII-(ZERO) THE NOBLE GASES:

i. Helium, neon, argon, krypton, xenon and radon are the members of group VIII.
ii. They are also called Noble gases, Inert gases or “Zero Group”.
iii. They are also mono atomic and low boiling gases.
iv. Their outer most shell is complete and these all elements are stable and are mostly chemically inactive and have no tendency to form compounds.
v. All the noble gases except radon are normally present in atmosphere i.e. argon present 1% in atmosphere by volume.
vi. By the process of liquefaction these gases can be changed in to liquid.

TRANSITION ELEMENTS:

i. Elements in groups IB, IIB through VIIB are known as Transition elements.
ii. They include the elements scandium, yttrium, lanthanum and actinium and the two rare earth series of elements lanthanides and actinides series (‘f’ block elements).
iii. They are also called “d” block elements. They have incomplete inner electron shells and are characterized by their variable valences and show similar behaviors.

iv. All transition elements are metals, in which the bonds between the atoms are very strong and they have high melting points.
v. They have an outstanding ability to form complex ion by coordination.
vi. The compounds are formed by coordinate covalent bonds.

THE POSITION OF METALS, NON-METALS AND METALLOIDS IN THE PERIODIC TABLE:

Position of metals:

i. Group IA (except hydrogen) IIA, IIIA, IB, IIB, the transition elements including lanthanides and actinide series are all classified as metals.
ii. Some elements of group IV and V-A are metals e.g. Pb, Bi etc.
iii. Metallic properties are pronounced as lower left hand corner of the periodic table.

Position of metals:

i. They are electro positive elements i.e. they lose electron to form Cat ions.
ii. They form basic oxides.
iii. They have luster (shine).
iv. They are malleable (i.e. can be spread out in to sheets).
v. They are ductile (i.e. they can be drawn in to wires).
vi. They are good conductors of heat and electricity.

Position of non-metals:

i. Majority of elements of P-block in groups III-A, VI-A, V-A, VII-A and V-III are metals.
ii. Non-metallic properties are pronounced in the upper right hand corner of the periodic table.

Properties of non-metals:

i. They are electronegative elements i.e. they gain electrons to form anions (negative ions).
ii. They form acidic oxides.
iii. They are bad conductors of heat and electricity.
iv. Most of them are gases.

METALLOIDS:

"The elements which show the properties of both metals as well as non-metals are called Metalloids."

Their oxides are atmospheric i.e. have basic as well as acidic nature.

Some examples of Metalloids.

i. Boron (B) in group III-A.
ii. Silicon (Si) and Germanium (Ge) in group IV-A.
iii. Arsenic (As) and Antinomy (Sb) in group V-A.
iv. Tellurium (Te) and Polonium (Po) in group VI-A.
v. Astatine of group VII-A.

PERIODIC TRENDS:

There are various trends in a group or family of elements given below:

i. Similar Properties:
   The elements show similar properties due to their similar electronic configuration.
ii. Regular Gradation:

A regular gradation in physical and chemical properties of elements in a group are observed due to gradual change in their electro negativities and atomic sizes.

iii. Size of Atom:
The first member of each group shows slightly different behavior from other members of that group. It is due to abnormally high electronegativity and small size of atom or due to remarkable difference in Atomic number.

iv. Metallic Character:
The metallic character or electro positivity of metals of 1^{st}, 2^{nd} and 3^{rd} group increases with increasing atomic number downward in the group.

v. Electro negativities:
The electro negativities of elements decrease with increasing atomic numbers. Thus among halogens, fluorine is the most electronegative and iodine the least.

APPLICATION OF PERIODIC TABLE:

Classification of periodic table in to periods and groups is very useful in the study of chemistry, as properties of elements are predictable on the basis of their position on the periodic table.

- Suggestion for further research is available.
- Prediction of new elements has been possible.
- Prediction of chemical characteristics of element is possible.
- Reactivity's of elements can be visualized.
- Atomic structure is cleared.
- Atomic number, mass etc. of atoms and such other basic informations are obtained from table.

SOME PERIODIC PROPERTIES OF ATOMS:

i. Atomic Radius.
ii. Ionization Energy.
iii. Electron Affinity.
iv. Electronegativity.

i. ATOMIC RADIUS:

"Half of the distance between the nuclei of two similar adjacent atoms is called Atomic Radius."

Unit of Measurement:

Atomic radius is measured in Angstrom Unit. It is represented by A.U.

Factors on which Atomic Radius depends:

Atomic radius depends up on following.

a. Number of shells.
b. Nuclear charge.

Periodic Trend:

a. Trend in Groups:

Atomic radius increases downward in a group due to addition of new shell.

b. Trends in Periods:

Atomic radius decreases left to right in a period due to increase in a nuclear charge by the addition of proton in nucleus. Nuclear charge pulls the orbiting electron with more force which reduces the size of atom.

ii. IONIZATION ENERGY (I.E OR I.P):

"The minimum amount of energy required to remove an electron from an isolated gaseous atom in its ground state is called ionization energy or ionization potential."

UNIT:

It is measured in kilo joule/mole (KJ/mol) or electron volt per atom (ev/atom).

Factors on which I.E depends:

The ionization energy depends up on atomic size and nuclear charge. The higher the I.E the more difficult is to remove an electron.

Trends in Group:

Ionization energy decreases downward in a group as the addition of a new shell decreases the hold of nucleus on valence shell.

Trends in a Period:

I.E increases left to right in a period, due to addition of proton in the nucleus increase the nuclear charge which increases the force of attraction on electron.

iii. ELECTRON AFFINITY:

"The energy change that occur when an electron is gained by an atom in the gaseous state is called Electron Affinity."

Unit:

It is measured in KJ/mol or in e.v per atom. EA for 1^{st} electron is negative i.e. Energy is released but for second electron EA is positive because energy has to be further added to overcome repulsion between negative ion and electron.

Factor on which Electron Affinity depends:

It depends up on the Atomic size and nuclear charge.

Trend in a Group:

Electron affinity decreases downward in a group because the addition of a new shell to each atom decreases its force of attraction.

Trend in a Period:

Left to right in a period E-A increases due to the increase in nuclear charge. Fluorine (F) has abnormally low electron affinity because due to its very small atomic size it does not accept electron easily.

iv. ELECTRONEGATIVITY:

"Electronegativity is the relative tendency of an atom in a molecule to attract a shared pair of electrons toward itself."

It is denoted by a number and has no unit.

Linus Pauling calculated the electro negativities of different elements taking fluorine as standard with its E.N = 4.

Trend in a Group:

E.N increases downward in a group as the power of nucleus to attract electron decreases due to increase in atomic sizes by the addition of an extra shell.

Trends in a Period:

E.N increases from left to right in a period due to increase in nuclear charge variation of electronegativity with atomic number and the periodicity in it.

EXERCISE

1. FILL IN THE BLANKS:

i. The rule of triad was introduced by **John Wolfgang Dobereiner**
ii. The repetition of properties after regular intervals is called **Periodicity**
iii. The longer period is **6** period and contains total **32** elements.
iv. The elements that contain both metallic and non-metallic characteristics are called **Metalloids**
v. The long form of periodic table contains **8** groups and **7** periods.
vi. According to Mendeleev the properties of the elements are the periodic functions of their **Atomic mass.**

CHEMICAL BONDING

The attractive force which binds two or more atoms of same or different elements is called a chemical bond."

REASON FOR BONDING:

Most atoms are not stable and are not capable of independent existence. It has been found that atoms which have outermost shells completely filled with two or eight electrons are stable. Only the atoms of noble gases (Group VIII-A) have completely outermost shell. This tendency is important base of chemical bonding.

Atoms of different elements tend to acquire their octet (eight electrons) or duplet (two electrons) in the outermost shell in different ways. They may tend to :

Lose electrons. OR Gain electrons OR share electrons.

TYPES OF CHEMICAL BOND:

There are two main types of chemical bonds.

i. Ionic bond.
ii. Covalent bond.

IONIC OR ELECTROVALENT BOND:

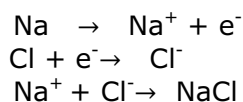
"The chemical bond formed by the complete transference of one or more electrons between two or more atoms is called electrovalent bond or ionic bond."

Explanation:

When an atom loses electrons equal to its valency form its outermost shell these electrons pass over to the outermost shell of another, by this transference, positive and negative atoms possessing stable electrons octets or duplets are formed. These charged atoms are called ions. Such oppositely charged ions then held together by an electrostatic force of attraction. This force of attraction is called electrovalent or ionic bond.

EXAMPLE: FORMATION OF AN IONIC BOND (NaCl).

Sodium loses one electron which is picked up by the chlorine atom in the result of which Na+ (sodium ion) and Cl- (chloride ion) are formed and in this way their outermost shells acquire eight electrons.

$$Na \rightarrow Na^+ + e^-$$
$$Cl + e^- \rightarrow Cl^-$$
$$Na^+ + Cl^- \rightarrow NaCl$$

These oppositely charged ions are held together by electrostatic force of attraction. In this way sodium chloride salt is formed.

EFFECT OF IONIZATION ENERGY ON IONIC BOND:

If an element has low ionization energy. It loses electron more easily to form cat-ion. The metal at the extreme left of the periodic table i.e. Group I-A have lowest ionization energies hence these metals have the strongest tendency to form ionic bonds with other elements. Most of the transition metals, some of the members of Group III-A and Tin (Sn) and Lead (Pb) usually form ionic bonds due to their lower ionization energies.

EFFECT OF ELECTRONEGATIVITY ON IONIC BOND:

"The tendency of an atom to attract electrons is called electronegativity."

It is obvious that atom having greater electronegativity gains electron more easily and form anion. Usually non-metals have greater electronegativity values. They have tendency to form anion consequently they form ionic bonds e.g. S, O, N, F etc.

PROPERTIES OF IONIC COMPOUNDS:

i. Ionic compounds are generally hard solids due to the strongest bonding forces.
ii. Ionic compounds have high melting and boiling point.
iii. They are soluble in water and their aqueous solutions contain ions.
iv. They are non-conductors in the solid state as the ions are not free to move. However they are good conductors of electricity in the fused (molten) and in an aqueous solution due to free movement of the ions, so they are electrolytes.
v. They are non-volatile.

THE COVALENT BOND:

"The chemical bond formed by the mutual sharing of electrons is called COVALENT BOND."

Explanation:

The idea of electron pair bond as covalent bonds was first introduced in 1916 by G, N. Lewis. A covalent bond is generally represented by a short straight line (-) between two bonded atoms. Each electron pair is attracted by the nuclei of bonded atoms.

Example:

In a molecule of methane. Carbon forms four covalent bonds with four atoms of hydrogen. Carbon and hydrogen atoms complete the electron in their outer most shell.

TYPES OF COVALENT BOND:

There are three types of covalent bonds.

i. Single covalent bond.
ii. Double covalent bond.
iii. Triple covalent bond.

SINGLE COVALENT BOND:

"A covalent bond formed by the mutual sharing of one electron pair is called a single covalent bond and it is denoted by single short straight line."

Example:

$$Cl - Cl \rightarrow Cl_2$$

When two atoms of chlorine combine, a pair of electrons is shared between these atoms. In this way each atom of chlorine has obtained eight electrons in its outermost shell.

DOUBLE COVALENT BOND:

"A covalent bond formed by sharing of two electron pairs is called double covalent and it is denoted by two short line (=)." E.g. O_2, C_2H_4 etc.

Example:

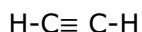
Ethane is an organic compound formed when two carbon atoms combine by sharing two pairs of electrons with each other.

TRIPLE COVALENT BOND:

"A three electron pairs bond is called a triple covalent bond and is denoted by three short lines (≡)."

Example:

In nitrogen there is a triple covalent bond between the atoms N_2 molecule. Similarly, in Ethyne two carbons are triple covalent bounded while C-H is a single bond.

H-C≡ C-H

DOT AND CROSS MODELS AND LEWIS FORMULA:

Models and formulae are used to express the covalent bonding. Some time with the help of dot and cross sharing of electrons is represented. Lewis also gave a method to represent the sharing, it is called Lewis formula.

DIFFERENCE BETWEEN IONIC AND COVALENT BOND:

IONIC COMPOUND	COVALENT COMPOUND
1)The ionic compounds are usually solid, hard and brittle	1)Covalent compounds exists all the three states i.e. solid, liquid and gas.
2)The ionic compounds don't conduct electricity in solid state but are good conductors of electricity either in the melted state or in the form of aqueous solution.	2)A pure covalent compound doesn't conducts electricity. Only polar covalent compounds can conduct electricity in their aqueous solution.
3)Ionic compounds have high melting point and boiling point.	3)Covalent compounds melt and boil at relatively lower temperature.
4)Ionic compounds are non-volatile.	4)Covalent compounds are mostly volatile.
5)Mostly ionic compounds are soluble in water but insoluble in petrol or kerosene etc.	5)Only polar covalent compounds are soluble in water but non-polar covalent compounds are insoluble and coordinate covalent compounds are sparingly soluble in water.

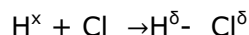
POLAR COVALENT BOND:

"The covalent bond formed between atoms having different electro negativities is called Polar covalent bond."

Explanation:

When a covalent bond is formed between two dissimilar electronegative atoms, the shared pair is always attracted more towards more electronegative atom. Hence that atom attains slightly negative charge and other atom attains slightly positive charge. Now both atoms are called negative pole and positive pole respectively such compounds are polar compound and bonds are called Polar bond e.g. HCl, NH_3, H_2O, HF etc.

Example:

$H^x + Cl \rightarrow H^{\delta}- Cl^{\delta}$

E.N value of H=2.1
E.N value of Cl=3.0
In case of hydrogen chloride, chlorine atom is much more electronegative than hydrogen atom, hence the shared pair of electrons is attracted more towards the chlorine atom and chlorine atom attain slightly negative charge and hydrogen become slightly positive charge that is why HCl is a polar compound.

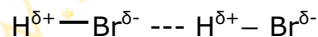
CHARACTERISTICS OF COVALENT COMPOUNDS:

i. Compounds with covalent bonds are usually made up of discrete units (molecule) with a weak inter molecular forces.
ii. In the solid state, there are weak vander wall forces between the molecules. Hence covalent compounds are often gases, liquids or soft solids with low melting point. In few cases, three dimensional covalent structure formed rather than discrete units, hence diamond and silica are covalent but are very hard and have high melting points. Usually covalent compounds have low melting and boiling points.
iii. They are insulator because they don't conduct electricity.
iv. Covalent compounds are usually insoluble in polar solvents like water, but soluble in organic solvents like benzene, ether, carbon tetra chloride etc.

DIPOLE-DIPOLE INTERACTION:

"The force of attraction present in between the two dipole molecules is called DIPOLE-DIPOLE INTERACTIONS."

In a polar covalent bond each atom carry partial positive and partial negative charge such bonds are described as DIPOLE. In such bond partial positive end attracts partial negative end of neighboring molecule.
The strength of their attraction depends on the difference between the electro negativities of the atoms, which for the polarized bond. The greater the difference in E.N value the stronger the polarization of the bond and the greater the dipole-dipole interaction.

$H^{\delta+} - Br^{\delta-}$ --- $H^{\delta+} - Br^{\delta-}$

THE HYDROGEN BOND:

"The inter molecular force in the polar molecules containing hydrogen atom is covalently bonded to atom of higher electronegative elements such as N, O, F etc is called HYDROGEN BOND." E.g. H2O.

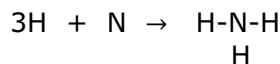
- The strongest hydrogen bonding present in HF where the molecules are held together in long chain like aggregates.
- The hydrogen bond is weak bond as compared to ionic and covalent bond that it is much strongest than other dipole-dipole interactions.
- They hydrogen bond has important effect on the physical properties of the compounds like HF, H_2O and NH_3.

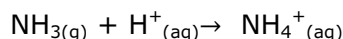
COORDINATE COVALENT BOND:

"The covalent bond in which a lone pair of electrons is provided by only one atom for sharing with other is called "Coordinate covalent bond."

Example:

When a nitrogen atom combines with three hydrogen atoms to form molecule of Ammonia, the Nitrogen atom is surrounded by the bonding pairs and a lone pair of electron.

3H + N → H-N-H
H

In certain cases, the lone pair can form another bond when Ammonia reacts with hydrogen ions in an aqueous solution of an acid, an Ammonium ion is formed.

$$NH_{3(g)} + H^+_{(aq)} \rightarrow NH_4{}^+_{(aq)}$$

In writing structures, the coordinate covalent bond is indicated by an arrow pointing towards the atom, which accepts the electron pair ($NH_3 \rightarrow H$).

EXERCISE

1. FILL IN THE BLANKS:
   - i. **Non-polar** covalent molecule is electrically neutral as well as symmetrical.
   - ii. The power of an atom to attract the shared pair of electrons towards itself is called**Electronegativity**.
   - iii. **Covalent** compounds are usually made up of discrete units; with weak intra molecular forces.
   - iv. NaCl is an **ionic** compound.
   - v. If electronegativity difference of bonded atoms is more then 1.7, the bond is called **Electrovalent.**
   - vi. The forces which hold atoms together in a molecule are called **intra molecular** force.
   - vii. The attraction between the partially positive hydrogen and negative F, O or N is called **Hydrogen** bonding.
   - viii. CO_2 is a **Non-polar** molecule.
   - ix. The atom which accepts a lone pair of electron is called **Acceptor**.
   - x. The electrostatic attraction between positive ions and the electrons of the atoms is called **Metallic** bond.

STATES OF MATTER

MATTER:

"Anything having mass and occupies space is called matter."

KINETIC MOLECULAR THEORY OF MATTER:

i. Matter is made up of very small particles i.e. molecules, atoms or ion.
ii. These molecules are in some state of motion, hence they possess kinetic energy. Their motion can be translational, vibrational and rotational.
iii. The molecules of these substances attract each other with a force which depends upon the distance between them. The force of attraction decreases with the increase of the distance between the molecules.
iv. Molecular motion depends on temperature. It increases with increase in temperature and decreases in temperature.
v. Molecular motion also depends on pressure. It increases with increase in pressure and decreases with decease in pressure.

STATES OF MATTER:

There are three common states of matter:

i. Solid state.
ii. Liquid state.
iii. Gaseous state.

i. SOLID STATE:

CHARACTERISTICS OF SOLIDS:

a. Solids have a definite shape and volume.
b. Molecules of solids are very close to each other and have no intermolecular spaces.
c. The intermolecular force of attraction between the molecules of solid is very large.
d. Solids are incompressible.
e. Solid can't diffuse in other solid in same state.
f. Molecules of a solid vibrate at their position.
g. Solid exert pressure on their bottom.

ii. LIQUID STATE:

CHARACTERISTICS OF LIQUIDS:

a. Liquids have definite volume but no definite shape.
b. The molecules in liquid have very little spaces between them.
c. The molecules of a liquid arrange themselves in the form of layer and these layers move over each other.
d. Liquid boils when molecular motion increases very much due to which their kinetic energy overcome the binding force and separate them.
e. Liquids exert pressure in their bottom.
f. Liquids are uncompressible.
g. Liquids can diffuse in each other.

iii. GASEOUS STATE:

CHARACTERISTICS OF GASES:

a. Gases neither have definite shape nor definite volume.
b. The molecules of gases are far away from each other.
c. Cohesive forces between molecules of gases are negligible.
d. Their molecules possess high kinetic energy due to rapid movement.

e. Gases are compressible.
f. Molecules of gases can diffuse in each other.

INTER CONVERSION OF THREE STATES:

MELTING:

"The phenomenon of conversion of solid into liquid is called melting."

When a solid is heated, the kinetic energy of the particles increases and the solid become hot. On continuous heating the heat energy overcomes the intermolecular forces holding the solid particles in fixed positions and it starts converting into liquid. This is called melting or fusion.

MELTING POINT:

"The temperature at which a solid starts converting into liquid is called melting point."

BOLING POINT:

"The temperature at which the vapor pressure of a liquid become equal to the atmospheric pressure and it starts converting into gas is called Boiling point."

EVAPORATION:

"The phenomenon of conversion of liquid into gas without boiling at all temperature is called Evaporation."

S.NO.	EVAPORATION	BOILING
1.	It takes place at all temperatures.	It takes place at certain fixed temperature. (different temperature for different material)
2.	It always take place at surface.	It takes place inside the liquid near from the source of heat.

SUBLIMATION:

"The phenomenon of conversion of solid directly into gas through a liquid state are called sublime solids."

SUBLIME SOLIDS:

"The solids which directly convert into gas without passing through a liquid state are called sublime solids. E.g. dry ice, camphor, naphthalene, ammonium chloride."

GRAHAM'S LAW OF DIFFUSION:

DIFFUSION:

"The movement of one gas molecules into the intermolecular space of other gas is called Diffusion."

STATEMENT OF GRAHAM'S LAW OF DIFFUSION:

"The rate of diffusion of gas is inversely proportional to the square of its density of the square root of the molecular masses of the gas."

Mathematical Form:

If r = rate of diffusion.
d = density of gas.
Then $r \propto 1/\sqrt{d}$
Or $r = K (1/\sqrt{d})$

Where 'K' is constant.

BROWNIAN'S MOTION:

"The continuous rapid zigzag motion of the suspended particle through a medium is called Brownian motion."

Explanation:

This phenomenon of molecular motion was first observed by Robert Brown in 1827 when he was examining a pollen grain suspended in a drop of water under microscope. He noticed that the pollen grain continually performing haphazard zigzag movements. The irregular constant movement was later found to be due to the collision of suspended particles (pollen grain) by the surrounding molecules of the liquid medium.

The Brownian motion understood by the following experiment:

Experiment:

Mix some powdered sulphur in water and stir it. After stirring filter the suspended sulphur. Some of the sulphur particles are very small and they can pass through pores of filter paper in to filtrate. Now put a drop of this filtrate on a slide and examine it under high microscope.

Result:

It is observed that sulphur particles perform zigzag motion through the medium and this motion is called Brownian motion.

Conclusion:

The Brownian movement of the suspended particles reflects the movement of the water molecules.

EXERCISE

1. Fill in the blanks:
   (i) There are **three** common states of matter.
   (ii) Gas possesses neither definite shape nor definite **volume**.
   (iii) All type of matter usually composed of smallest particles which are always in **motion**.
   (iv) The temperature at which liquid starts boiling is called **boiling** point.
   (v) The **liquid** is the intermediate state between solid and gas.
   (vi) **Evaporation** is the escape of molecules from the surface of liquid.

SOLUTION AND SUSPENSION

SOLUTION:

"Homogenous mixture of two or more substance is called a Solution."

Examples:

- Salt and water uniformly mixed to form a solution.
- Sugar and water uniformly mixed to form a solution.
- Zinc and copper are mixed by melting them together uniformly to form solution called brass.

SOLUTE:

"The substance which is to be dissolved in other substance to form a solution and present in lesser amount is called a solute."

Example:
Sugar and salt are used as solute in their respective.

SOLVENT:

"The substance which dissolves other substance in it and present in generally greater amount is called a solvent."

Example:
Water is used as a solvent in the aqueous solutions of all the substances.

Types of solution with respect to the quantity of solute:

Saturated solution:

"The solution which contains maximum amount of solute and can't hold more solute in it at a particular temperature and pressure is called saturated solution."

Super saturated solution:

"The solution which contains more amount of solute than its holding capacity at particular temperature and pressure is called super saturated solution."

Unsaturated solution:

"The solution which contains lesser amount of solute than its holding capacity at particular temperature and pressure is called unsaturated solution.

Preparation of an unsaturated solution:

Take few crystals of sugar and dissolve them in water. This results in an unsaturated solution, because the solution has a capacity to dissolve more crystals of sugar (solute) at a given temperature.

Preparation of saturated solution:

Take some sugar and dissolve in a beaker containing 100 ml of after. After dissolving those crystals, add more sugar until the added crystals start to settle down at room temperature. This solution is called saturated solution.

Preparation of super saturated solution:

To prepare super saturated solution take a saturated solution and dissolve more solute by increasing temperature or pressure (where it effect) and a

solution forms which contain more solute than its holding capacity at room temperature.
Types of solutions:

Solute	Solvent	Examples
Solid	Solid	Alloys such as brass (copper and zinc). Bronze (copper and tin). Steel (carbon and iron). Glass.
Solid	Liquid	Sugar in water. Salt in water. Sea water.
Solid	Gas	Smoke (carbon particles in air).
Liquid	Solid	Amalgam (e.g. mercury in sodium). Water in jelly powder.
Liquid	Liquid	Water in milk. Milk in tea. Alcohol in water. Vinegar (acetic acid in water).
Liquid	Gas	Cloud (water vapor in air). Steam.
Gas	Solid	Hydrogen gas absorbed over palladium. Platinum metal surface.
Gas	Solid	Carbonated soft drinks such as Pepsi etc. Ammonia gas in water. Air dissolved in water.
Gas	Gas	Air is the homogenous mixture of 78% N_2, 21% O_2 and 1 % other gases.

SOLUBILITY:

"Maximum amount of solute which is required to saturate 100g of solvent (water) at particular temperature or pressure is called solubility."

FACTORS AFFECTING SOLUBILITY:

Following factors affect solubility.

i. Temperature.
ii. Pressure.
iii. Nature of solute or solvent.

i. AFFECT OF TEMPRATURE ON SOLUBILITY:

a. Affect of temperature on the solubility of solid and liquids in liquid:

The solubility of solid in liquid or solubility of partially miscible liquids increases with increase in temperature.

For example: The solubility of sugar on water at 0^oC is 179 g/100ml whereas at 100^oC it is 487 g/100ml.

b. Affect of temperature on the solubility of gases in liquids:

The solubility of gases in a liquid decreases with the increase in temperature. For this reason when a glass of cold water is warmed, bubbles of air are seen on the inside of the glass.

ii. AFFECT OF PRESSURE ON SOLUBILITY:

Henry's law:

"Solubility of a gas in a liquid is directly proportional to the pressure of gas."

$$m \propto P$$
$$m = K P$$

Where

m = amount of gas dissolved.
K = Constant.
P = Pressure.

a. Affect of pressure on the solubility of solids and liquids in liquids:

There is no effect of pressure on the solubility of solids and liquids in liquids.

b. Affect of pressure on the solubility of gases in liquid:

The solubility of gases in liquid increase by the increase in pressure like carbonated drinks (soft drinks i.e. 7up, sprite etc.). CO_2 is filled with slightly greater than One atmospheric pressure because at one atmosphere it is not good soluble. When the bottles are opened pressure decreases, so solubility of CO_2 also decreases, hence bubble of CO_2 come out from solution.

iii. AFFECT OF NATURE OF SOLUTE ON SOLUBILITY:

Solubility of a substance works with a proverb "LIKE DISSOLVE LIKE."

Therefore

- Ionic solids are only soluble in polar solvent being similar in charge like common salt and many other ionic substances are soluble in water because water is polar.
- Polar substances are soluble in polar solvents like sugar; HCL etc. are soluble in water because water is a polar compound.
- Non-polar substances are soluble in non-polar solvents like oil, grease, nail polish are soluble in solvent like alcohol, benzene, thinner, petrol etc.

CRYSTALLIZATION:

"The process of formation of geometrical shaped solid substances is called Crystallization."

PROPERTIES OF CRYSTALLIZATION SUBSTANCES:

i. They have sharp melting points.
ii. They have regular and definite shapes.
iii. They contain water molecules called water of crystallization.
iv. They are homogenous solids.

PROCESS OF CRYSTALLIZATION:

To prepare crystals of any material first a super saturated solution of that solid is prepared at high temperature and allowed to cool down, then at lower temperature it can't hold more solute in dissolve state, some of the dissolved solute particles come out of solution in solid from having regular and definite geometrical shape which are called Crystals.

PREPARATION OF CRYSTALS OF COPPER SULPHATE $CuSO_4.5H_2O$ (BLUE VITRIOL):

To prepare the crystals of copper sulphate first its saturated solution is prepared in a beaker at room temperature and then more quantity of copper sulphate is added to make super saturated solution by heating and stirring the solution continuously with a glass rod. Now allow this super saturated solution to cool down at room temperature. Upon cooling and standing, Blue vitriol crystals of copper sulphate formed. The shape of these crystals can be observed under light microscope.

PREPARATION OF CRYSTALS OF POTASSIUM NITRATE (KNO_3):

To prepare the crystals of potassium nitrate first its 100 ml saturated solution is prepared in beaker at room temperature by dissolving 37g of solute and then add 20g more to make super saturated solution by heating up to 50°C and stir the solution continuously with a glass rod. Filter the hot super saturated solution and collect filtrate in another beaker and then allow it to cool down at room temperature. Upon cooling crystals of potassium nitrate are formed. Filter the crystals and then their shape can be observed under light microscope.

PURIFICATION OF SOLIDS BY CRYSTALLIZATION:

Following are the steps with the help of which solid can be purified through crystallization:

i. Preparation of super saturated solution.
ii. Filtrate of hot super saturated solution.
iii. Formation of crystals.
iv. Filtration of crystals.
v. Filtration and drying of crystals.

i. Preparation of super saturated solution:

Take 50 ml of water in a beaker and add the impure sample (40g) of KNO_3 to it while stirring with glass rod. Supply heat gently till the temperature of the solution is above 50°C stir the solution at this temperature till most of the solid is dissolved.

ii. Filtration of hot super saturated solution:

Filter the hot solution and collect residue on the filter paper and collect the filtrate in another beaker.

iii. Formation of crystals:

On cooling, the crystals of potassium nitrate will start appearing.

iv. Filtration and dying of crystals:

When no more crystals are formed, filter it again and collect filtrate in a beaker. Purified crystals of KNO_3 are obtained on the filter paper and then dry the crystals by keeping them in between dry filter paper to observe.

Note:

The filtrate contains some quantity of the dissolved KNO_3 along with the NaCl, being a soluble impurity.

CONCENTRATION OF A SOLUTION:

"The amount of solute dissolve in a definite amount of solvent or solution is called concentration."

It can be expressed in following ways:

i. Molarity.
ii. Molality.
iii. Mole fraction.
iv. Percentage concentration.
v. Normality.

i. MOLARITY:

"Number of moles of solute dissolved in a litre or dm^3 of a solution is called molarity."

Formulae:

M = (Number of moles of solute) / (volume of solution in litre or dm^3)

M = (Mass of solution in gram) / (gram formula mass or grammolecular mass x volume of solution in litre or dm^3)

M = (Mass of solute in gram x 1000) / (Gram formula mass or gram molecular mass x (volume of solution in ml or cm^3)

UNIT:

Molarity is measure in moles per litre or cubic decimeter.

Molarity = mol/litre or dm^3

NAMES OF SOLUTIONS ACCORDING TO THEIR MOLARITIES:

MOLAR SOLUTION = 1 mol/dm^3.
SEMI MOLAR SOLUTION = 0.5 mol/dm^3.
BIMOLAR SOLUTION = 2 mol/dm^3.
TRIMOLAR SOLUTION = 3 mol/dm^3.
DECIMOLAR SOLUTION = 0.1 mol/dm^3.

ii. MOLALITY:

"Number of moles of solute dissolve in a kilogram of solvent is called molality."

Formulae:

M = (Number of moles of solute) / (Mass of solvent in kilogram).

M = (Mass of solute in gram) / (Gram formula mass or gram molecular mass x mass of solvent in Kg).

M = (Mass of solute in gram x 1000) / (Gram formula mass or gram molecular mass x mass of solvent in Kg).

UNIT:

Molality is measured in moles per kilogram.

Molality = mol/kg.

NAMES OF SOLUTION ACCORDING TO THEIR MOLALITIES:

MOLAL SOLUTION = 1 mol/Kg.
SEMI MOLAL SOLUTION = 0.5 mol/Kg.
BIMOLAL SOLUTION = 2 mol/Kg.
TRIMOLAL SOLUTION = 3 mol/Kg.

iii. MOLE FRACTION:

"The relation between the number of moles of either solute or solvent and the sum of moles of solute and solvent is called Mole fraction."

Mole fraction = (number of moles of solute or solvent) / (sum of moles of solute and solvent)

If

Number of moles of solute = n_1.
Number of moles of solvent = n_2.

Then

Mole fraction of solute = $n_1 / (n_1+n_2)$

iv. PERCENTAGE CONCENTRATION:

"The amount of solute dissolved in 100 parts of solvent is called percentage solvent."

It is expressed in following ways:

i. Mass by mass percentage concentration (m/m %).
ii. Mass by volume percentage concentration (m/v %).
iii. Volume by mass percentage concentration (v/m %).
iv. Volume by volume percentage concentration (v/v %).

i. Mass by Mass percentage concentration:

If both solute and solvent are taken on the basis of their masses is called mass by mass percentage concentration.

m/m %age conc. = (mass of solute/mass of solution)x 100%

Example:

25 % m/m conc. Of NaOH solution means 25 g of NaOH dissolved in 75g of water to make 100 g of solution.

ii. Mass by volume percentage concentration:

If a particular mass of solute is dissolved in a definite volume of solution, the percentage concentration is called mass by volume percentage concentration.

m/v %age conc. = (mass of solute/volume of solvent or solution)x 100%

Example:

15% m/v conc. Of NaCl solution means 15g of NaCl dissolved in 100 cm^3 of solution.

iii. Volume by mass percentage concentration:

If a particular volume of solute is dissolved in a particular mass of solution, the percentage concentration is called volume by mass percentage concentration.

v/m %age conc. = (volume of solute/mass of solvent or solution)x 100%

Example:

20 % v/m conc. Of HCl solution means 20 cm^3 of HCl dissolved in 100g of solution.

iv. Volume by volume percentage concentration:

If both solute and solvent are taken on the basis of their volumes is called volume by volume percentage concentration.

v/v %age conc. = (volume of solute/volume of solvent or solution)x 100%

Example:

30 % v/v conc. Of acetic acid solution means 30 cm^3 of acetic acid dissolved in 70 cm^3 of water to make 100 cm^3 of solution.

SUSPENSION:

A heterogeneous mixture consists of visible particles, each of which contains millions of molecules surrounded by molecules of liquid is called suspension.

Properties of Suspension:

i. The size of their particles is 1000 nm.
ii. Particles of suspension can be seen through low power microscope.
iii. They are heterogeneous mixtures.
iv. Their particles settle down.
v. They are not transparent.
vi. Their components can be separated by filtration.

Example:

i. Smoke: A suspension of the particles of carbon in a gas or air.
ii. Mud (slime): A suspension of fine particles of soil in small amount of liquid.
iii. Foam (froth): A suspension of fine particles of gas in liquid.
iv. Emulsion: A suspension of droplets of one liquid into another in which it is not soluble:

DIFFERENCE BETWEEN SUSPENSION AND SOLUTION:

S/NO	SOLUTION	SUSPENSION
1	The size of their particles is 0.1 nm to 1 nm.	The size of their particles is 1000 nm.
2	Particles of solution can't be seen through low power microscope.	Particles of suspension can be seen through low power microscope.
3	They are homogeneous mixture.	They are heterogeneous mixture.
4	Their particles don't settle down.	Their particles settle down.
5	They are generally transparent.	They are not transparent.
6	Their components can't be separated by filtration	Their components can be separated by filtration.

EXERCISES

1. Fill in the blanks:
   i. The most common solvent in nature is **water**.
   ii. An **aqueous** is the solution when the liquid solvent is water.
   iii. 10 % solution contain 10gm solute, dissolved in **90** g solvent.
   iv. **M** is the symbol for the concentration unit of molarity.

2. Calculate molarity of solution containing 16 gm glucose per 300 ml solution.

DATA:

Given:

Mass of solute = 16 g.
Volume of solution = 300 ml.
Gram formula mass of glucose = 180 g.

Required:

Molarity =?

Formula:

M = (Mass of solute in gram x 1000) / (Gram formula mass or gram molecular mass x (volume of solution in ml or cm^3)

Solution:

M = (16 X 1000) / (180 X 300)

Answer: Molarity = 0.296 mol. /dm^3

3. Find the mass of sucrose (Molecular Mass = 342) required to be dissolved per 60 cm^3 solution to prepare a semi molar solution.

DATA:

Given:

Molarity = semi molar = 0.5 mol. /dm^3.
Volume of solution = 600 cm^3.
Gram molecular mass of sucrose = 342 g.

Required:

Mass of solute =?

Formula:

Mass of solute= (Molarity x gram formula mass of solute x volume of solution in cm^3)/1000

Solution:

Mass of solute = (0.5 x 342 x 600)/1000
Mass of solute = 102.6 g

Answer:

Mass of sucrose = 102.6 g.

4. 5.3 gm Na_2CO_3 was dissolved in 800g water, calculate the molality of solution.

DATA:

Given:
Mass of solute = 5.3 g.
Mass of solvent = 800 g.
Gram formula mass of Na_2CO_3 = 106 g.

Required:
Molarity =?

Formula:
M = (Mass of solute in gram x 1000) / (Gram formula mass or gram molecular mass x (Mass of solvent in kg)

Solution:
Molality = (5.3 x 1000) / (106 x 800)

Answer:
Molality = 0.0625 mol. /kg

ELECTROCHEMISTRY

"The branch of chemistry that deals with the relationship between electricity and chemical reactions i.e. with the conversion of electrical energy in to chemical energy and chemical energy into electrical energy is known as electrochemistry."

ELECTROLYTES:

"The chemical compound which conducts electricity in molten condition or through its aqueous solution with chemical change is called an electrolyte."

Examples:

All acids, bases and salts are electrolytes (in aqueous solutions or fused state).

Hydrochloric acid (HCl).
Sulphuric acid (H_2SO_4).
Sodium hydroxide (NaOH).
Sodium chloride (NaCl).
Copper sulphate ($CuSO_4$) etc.

Explanation:

No substance can be electrolyzed unless it conducts electricity. But all the conductors are not electrolytes. Electric current can pass through a metal for years but it will not decompose. Metals are good conductors but are not electrolytes.

All electrolytes are ionic compounds or polar compounds like acids and bases. Salts are ionic compounds and are solids. These solids do not conduct electricity because in the solid state these ions are tightly packed or held together showing no movement of the ions. They cannot move. However when an ionic solid is melted or dissolved in water, its ion become free to move. Thus ionic compounds in molten states or in aqueous solution conduct electricity. This conduction due to the free movement of ions

NON-ELECTROLYTES:

"The chemical compounds which do not conduct electricity in molten or in aqueous solution are called non-electrolytes."

Example:

Sugar, petrol. Benzene etc.

ELECTROLYSIS OR ELECTROLYTIC CONDUCTION:

Movement of the ions of an electrolyte to towards their respective electrodes and their deposition or liberation as neutral species under the influence of electric current is called electrolysis.

The cell used for the reaction to occur by passing electric current is called electrolytic cell. Thus electrolytic cell is a device which is used to convert electrical energy into chemical energy (a non-spontaneous chemical reaction takes place by the loss and gain of electrons) for example: a device or electroplating or electrolysis of water in the presence of an acid. The process is called electrolysis or electrolytic conduction.

ELECTROLYSIS OF MOLTEN SODIUM CHLORIDE:

Sodium chloride (salt) does not conduct electricity in the solid state. To make it conduction electricity, either fuse or melt the salt or dissolve it in water. So there are two ways of doing electrolysis of sodium chloride. We are doing electrolysis of molten sodium chloride. Sodium chloride melts at 800^{o}C. It is easy

to predict the result of electrolyzing a molten electrolyte. The salt just splits into two parts. Sodium (metal) positive ion (Na^+) and chloride (non-metal) negative ion (Cl^-). We can write the ionization reaction as.

NaCl $Na^+ + Cl^-$

In sodium chloride, the ions are held together tightly in a regular lattice arrangements. In solid the ions cannot move but when sodium chloride is melted, the ions are free from their lattice and they can move freely to conduct electricity.

Some fused NaCl is taken in an electrolytic cell i.e. in a glass vessel. Two platinum rods (electrodes) are dipped in to the used salt (NaCl). The two electrodes are connected to a source of electricity i.e. to a battery outside the cell by wires. The electrode connected to the negative i.e. to a battery outside the cell by wires. The electrode connected to the positive terminal of the battery is called anode.

When an electric potential is applied through the molten sodium chloride salt, electrolysis starts. The positive ions i.e. Cat ions (Na^+) are attracted towards cathode and the negative ions i.e. anions (Cl^-) are attracted towards anode. At the two electrodes following chemical reactions are taken place.

At Cathode:

Sodium ions (Na+) which are positively charged move towards cathode and gain electrons to get neutralized. Thus Na^+ ions are discharged at cathode and form neutral molten sodium metal. We can represent the happening at cathode as:

Sodium ion + electron Sodium metal

$Na^+ + e^-$ Na

At Anode:

Chloride ions which are negatively charged moved towards anode i.e. Cl^- ions have one electron in excess. The anode has a shortage of electrons and is positively charged. When Cl^- ions arrive at anode, forming neutral chlorine (Cl) atoms but we know that Cl atoms do not exist in Free State. They combine to form Cl_2 molecules. So Cl^- ions are discharged at anode to liberate Cl_2 gas by the loss of electrons at anode.

Chloride ion Chlorine atom + e^-

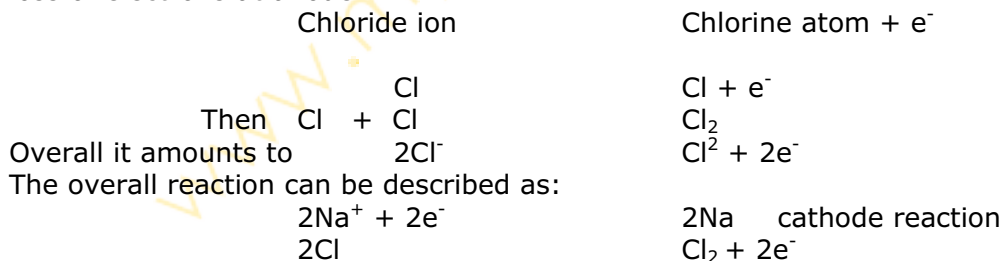
Cl Cl + e^-

Then Cl + Cl Cl_2

Overall it amounts to $2Cl^-$ $Cl^2 + 2e^-$

The overall reaction can be described as:

$2Na^+ + 2e^-$ 2Na cathode reaction

2Cl $Cl_2 + 2e^-$

On adding the two reactions, the loss and gain of electrons cancel we get final result:

$2Na^+ + 2e^-$ 2Na cathode reaction

$2Cl^-$ $Cl_2 + 2e^-$

NET ELECTROLYSIS REACTION:

$2Na^+ + 2Cl^-$ $2Na + Cl_2$

The electrolysis of molten sodium chloride shows that we get sodium metal at cathode and Cl_2 gas is liberated at anode.

FARADY'S FIRST LAW OF ELECTROLYTES:

"The mass of an element discharged during electrolysis is directly proportional to the magnitude of electric current and the time of flow of current."

Explanation:

According to the law

$$W \propto A \times t$$
$$W = Z \times A \times t$$

Where

W = mass of element deposited
Z = electrochemical equivalent of the substance
A = amount of electric current in ampere
T = time in seconds

FARADY'S SECOND LAW OF ELECTROLYSIS:

It states that:

"The mass of different substance deposited or liberated when same quantity of current is passed through different electrolytes, connected in series are proportional to their chemical equivalent masses."

Explanation:

Consider three different electrolytes $AgNO_3$ $CuSO_4$ and $Al_2(NO_3)_3$ solutions connected in series. Same quantity of current is passed through them and then the masses of Ag, Cu and Al deposited on their respective electrodes would be directly proportional to their equivalent masses.

According to faraday if exactly 96500 coulombs of electric charge is passes then the mass of an element deposit would equal to their equivalent masses.

For example:

By passing 96500 coulombs Ag deposited would be equal to 108g, that of copper is 31.75g and Al is 9g which are their equivalent masses respectively.

ELECTRO CHEMICAL EQUIVALENT (Z):

The amount of deposited or liberated substance during electrolysis when one coulomb charge is passed through an electrolyte is called electrochemical equivalent of that substance.

S.I unit of it is expressed in Kg/coulomb.

Each element has its own chemical equivalent.

Relationship between equivalent and electrochemical equivalent:

Since 96500 C electric charge is required to liberate one gram equivalent mass of substance, so it is clear that the 1 gram equivalent mass of a substance is 96500 times greater than its electrochemical equivalent.

Gram Eq. mass =96500 x Z

In other words

C = 96500 x Z or e = F x Z

$$Z = e/96500 \text{ or } Z = e/F$$

Where e = Gram equivalent mass
F = Faraday = 96500 coulombs
Z = E.C.E = electrochemical equivalent

EQUIVALENT MASS OF SOME ELEMENT:

Equivalent mass of an element =Atomic mass of the element /valency of the element

i. Equivalent mass of silver Ag = 108/1 = 108
ii. Equivalent mass of copper = 63.5/2 = 31.75

ELECTRIC CURRENT:

"The flow of charge in the unit of time is called electric current and its S.I unit is Ampere."

Ampere:

The current when passed through a circuit for one second, can liberate 0.001118 gram from silver nitrate solution is called an Ampere.

COULOMB:

Coulomb is the S.I unit of electric charge.

If one ampere of electric current is passed for one second, then the quantity of charge is known as a coulomb.

Electric charge = A x t
1 Coulomb = 1 Ampere x 1 Second

FARADAY:

The current of 96500 coulombs charge is called one faraday (F) charge. The name is given after the name of faraday.

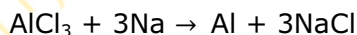
USES OF ELECTROLYSIS:

Electrolysis is an important process,

i. For the extraction of certain metals from their ores.
ii. Electroplating.

i. EXTRACTION OF ALUMINIUM:

Aluminum is a reactive metal which makes it difficult to extract it from its ore. Earlier it was obtained by heating its salt aluminum chloride with sodium metal. Sodium itself as expensive which made it even more expensive.

$$AlCl_3 + 3Na \rightarrow Al + 3NaCl$$

Now a days Al is extracted by the electrolysis of Alumina which is obtained from cheap ore of Al bauxite. Due to the process of electrolysis. Aluminum is so cheap that it is used in dispose able plates for eating.

ii. EXTRACTION OF SODIUM:

Sodium metals is extracted by the electrolysis of molten sodium chloride to deposit sodium (Na) metal at cathode by Down's process. Many metals are purified into pure metals by the process of electrolysis.

iii. EXTRACTION OF COPPER:

Impure copper is purified by the process of electrolysis. In this process. The impure copper i.e. blister copper is made as anode in the electrolytic cell.

Cathode is a thin plate or sheet of pure copper metal and the two electrodes are dipped in the electrolytic solution of copper sulphate containing few drops of sulphuric acid. The two electrodes are connected with a battery. When an electric current is passed through the electrolytic solution. The copper anode dissolves in the solution as Cu^{++} ions which move towards cathode and gain electrons to get neutralized, depositing pure copper metal over cathode plate. Most of the impurities of anode fall to the bottom of the cell, called as "anode mud". Copper thus deposited at

cathode is 99.99% pure. In this way copper anode dissolves completely to form pure copper at cathode. This process of electrolysis is similar to electroplating.

ELECTROPLATING:

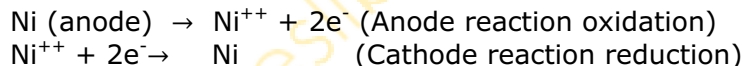
"The coating of one meta on other metal through the process of electrolysis in order to protect the baser metal from corrosion and to make them more attractive is called electroplating."

EXPLANATION:

Electroplating is the process of electrolysis which is used to coat one metal onto another. Usually the object to be electroplated is made up of cheaper or baser metal, such as iron, steel etc. It is then coated with a thick layer of more attractive corrosion – resistance and costly metal, like silver, gold, chromium, tin etc. The cost of the finish product is far less than the object entirely made of these metals. Gold coated object is much cheaper than the gold object.

Nickel Plating:

A cell is used for electroplating of nickel. A piece of pure metal is the anode and the spoon or any object to be plated is cathode. A solution of sulphate ($NiSO_4$) is used as the electrolyte in the electrolytic cell. The two electrodes are joined with a battery. On passing the electric current, the anode which is Ni dissolves in the electrolytic solution forming Ni^{2+} ions by the loss of electrons. Ni^{++} ions from the solution move towards the cathode, where they gain electrons and are reduced to Ni metal on the surface of spoon (cathode).

$$Ni\ (anode) \rightarrow Ni^{++} + 2e^- \quad \text{(Anode reaction oxidation)}$$
$$Ni^{++} + 2e^- \rightarrow Ni \quad \text{(Cathode reaction reduction)}$$

The net reaction is simply the transfer of Ni as Ni through $NiSO_4$ solution towards the cathode i.e. spoon and get it coated with Ni metal on the surface. The sum of reduction and oxidation is:

$$\underset{\text{(Anode)}}{Ni} \rightarrow \underset{\text{(Cathode)}}{Ni}$$

ELECTROCHEMICAL CELLS:

"The cell which is used to convert chemical energy into electrical energy or vice versa is called electrochemical cell."

GALVANIC OR VOLTAIC CELL:

"An electrochemical cell which converts chemical energy into electrical energy is known as Galvanic or voltaic cell."

The simplest of the cell Galvanic or Voltaic cells is Daniel cell.

DANIELL CELL:

A Daniel cell is the simplest of the Galvanic or Voltaic cell which is used to convert chemical energy into electrical energy spontaneously.

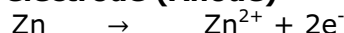
Construction:

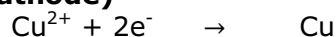
Daniel cell consists of two half cells. One half cell is Zinc rod dipped in 1M $ZnSO_4$ Solution and the other half cell is copper rod dipped in 1M $CuSO_4$ solution. The two half cells are connected together to form a complete cell. The two half cells or single electrodes are connected together to form a complete cell. The two half cells are separated from each other by a porous partition or a salt bridge (KCl).

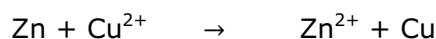
Process:

When both the electrodes are connected externally through a voltmeter by means of metal wire. The cell starts producing electric current at once. Zn undergoes oxidation to form Zn^{2+} ions by the loss of two electrons to go in to $ZnSO_4$ solution. Zn acts as anode or negative electrode. The electrons which are free at Zn electrode travel through the wire externally to cu electrode. These electrons are accepted by $Cu2^+$ ions of $CuSO_4$ solution and Cu^{2+} ions undergo reduction to deposit copper metal at Cu electrode which acts as cathode or positive electrode. In this process Zn electrode dissolves in the solution of $ZnSO_4$ and reduces in size, while copper electrode grows in size due to the deposition of Cu metal.

Cell reaction at Zn electrode (Anode)

$$Zn \rightarrow Zn^{2+} + 2e^-$$

At Cu electrode (Cathode)

$$Cu^{2+} + 2e^- \rightarrow Cu$$

The total cell reaction is the sum of two half-cell reactions.

$$Zn + Cu^{2+} \rightarrow Zn^{2+} + Cu$$

The function of salt bridge or porous partition is to prevent the mixing of two solutions ($ZnSO_4$& $CuSO_4$) and allows the ions to move through from one part to another. Zn^{2+} ions from the anode compartment move in to the cathode compartment through the porous partition or salt bridge. It maintains the electrical neutrality in the two electrolytic solutions.
The cell voltage in Daniel cell is 1.10 volt.

BATTERIES:

In everyday life, we use the devices to produce electricity by the chemical reactions. Known as batteries. A flash light battery consists of single voltaic cell with two electrodes in contact with one or more electrolytes.
Sometimes a distinction is made between the terms cell and battery. A battery is an assembly of two or more voltaic cells, connected together in series. By this definition automobile or motor battery is a true battery. The most common types of cells or batteries are described as follows:

Dry cell:

It is a primary cell, which is used to convert chemical energy into electrical energy. It is used in most of the flash lights, calculators, clocks and in portable devices. It is an irreversible cell.

Construction:

In a dry cell there is an outer zinc vessel which acts as anode and inner carbon (graphite) rod which acts as cathode. The graphite rod is surrounded by a mixture of manganese dioxide and carbon powder. The electrolyte is a moist paste of Ammonium chloride and zinc chloride. The cell is called a dry cell into a gel like paste by an agent such as starch. The upper top position of the cell is sealed with wax. A copper cap is fitted on the top of carbon rod (cathode) to make the electrical contact. The whole cell is covered with a safety cover.

Working:

When a zinc and graphite electrodes are connected by a metallic wire, Zn gets oxidized to form Zn^{2+} which pass into the wet paste leaving behind electrons

on the Zn container and the electrons move from Zn electrode to carbon electrode through the external circuit. The cell reactions are complex.

Lead-storage battery (Motor-Battery):

Lead storage battery is used in automobiles. It is a secondary battery and is a reversible cell which can be restored to its original condition. The battery can be used through repeated cycles of discharging and recharging.

Construction:

There are several anodes and several cathodes which are connected together in series; about six cells are connected together. Each cell has a voltage of 2V and overall voltage when six cells are connected together in series would be 12V.

In lead storage battery anodes are lead alloy and cathodes are made up of red lead oxide. The electrolyte is dilute sulphuric acid. Which having concentration of 30%.

Discharging:

As the cell reaction proceeds $PbSO_4$ precipitates and partially coats both the electrodes, sulphuric acid is diluted because more and more water is formed. The battery is said to be discharged.

Recharging:

Now by connecting the battery to an external electrical source, we can force the electrons to flow in the opposite direction i.e. the net cell reaction can be reversed and the battery is recharged.

EXERCISE

Q1. A current of 0.5 ampere was passed through a solution $CuSO_4$ for one hour. Calculate the mass of copper metal deposited on the cathode. Electrochemical equivalent of Cu= 0.000329 g/C = 3.29×10^{-4} or 3.29×10^{-7} Kg/C.

DATA:

Given:

Current in ampere (A) = o.5 ampere

Time in second (1 hr.) = 1 x 60 x 60 = 3600s

Z for Cu metal = 3.29×10^{-4} g/C or 3.29×10^{-7} Kg/C

Required:

Mass of copper deposited = W?

FORMULA:

W = Z x A x t

Solution:

$W = 3.29 \times 10^{-7} \times 0.5 \times 3600$

$W = 5.929 \times 10^{-4}$ Kg

Mass of copper metal deposited 5.929×10^{-4} Kg

Q2. A current of 10A was passed for 15 minutes in a solution of silver nitrate. The mass of silver deposited was found to be 1.0062×10^{-2} Kg. Calculate the electrochemical equivalent (Z) of Ag metal.

DATA:

Given:

Current = 10 A
Time in seconds = 15 x 60 = 900 s
Mass of Ag metal (W) = 1.0062×10^{-2} Kg or $1.0062 \times 10^{-2} \times 1000$ g

Required:
Electrochemical equivalent = Z=?

FORMULA:
W = Z x A x t
Z = W/ (A x t)

Solution:
Z = 10.062/ (10 X 900)
Z = 0.001118 g/c ANSWER

Q3. If constant current was passed for 5 hours and 404 mg of Cu was deposited. Calculate the current passed through $CuSO_4$

DATA:
Given:
Amount of Cu deposited = W = 404mg = 0.404g
Time = 5 hours = 5 x 60 x 60 = 18000 seconds
Gram equivalent mass of Cu = 63.5/2 = 31.75
Required:
The amount of electric current =?

FORMULA:
A = (96500 x W) / (e x t)
A = (96500 x 0.404) / (31.75 x 18000)
A = 0.0682 Ampere

1. Fill in the blanks:
   i. The substance used for electrolysis is called **Electrolyte.**
   ii. When molten sodium chloride is electrolyzed **sodium metal** is formed at cathode.
   iii. One faraday is equivalent to **96500** coulombs.
   iv. The electrolyte in lead storage battery is **sulphuric acid.**
   v. Dry cell is a **primary** cell.

ACID BASES AND SALTS

INTRODUCTION:

Acid and bases were recognized as the two groups of substances in the 15th century by Muslim chemists.

In modern, it was recognized that substances having sour taste were called acids. They also recognized another group of substances having bitter taste and used as cleaning agents were called bases. Neutralization was also recognized in early 16th century.

ACID IN DAILY LIFE:

Orange and grape contain citric acid. All citreous fruits contain large amount of ascorbic acid or vitamin C.

BASES IN DALY LIFE:

Bases are also common in use of house hold Ammonia solution. It is used as cleaning agent. Lye is commercial used for cleaning sink-drains. Milk of magnesia is used as an anti-acid.

SALTS:

Salts are formed as the result of neutralization having positive and negative ions. Salts are not only neutral, they may behave like acids or bases.

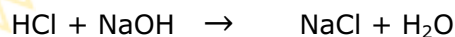
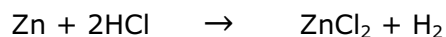
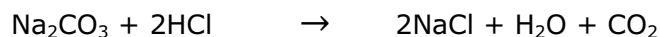
PROPERTIES OF ACIDS AND BASES:

PHYSICAL PROPERTIES OF ACIDS:

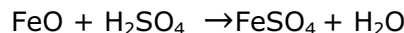
1. Acids have sour taste.
2. They change the color of methyl orange and blue litmus to red.
3. Acids are electrolytes that means aqueous solution of acids contains electricity.
4. In human stomach 0.4% of gastric juice contains hydrochloric acid for proper digestion.
5. Acids destroy fabrics, skin and human tissues etc.

CHEMICAL PROPERTIES OF ACIDS:

Acid react with bases, metals, non-metals and other things etc. some of the properties are given below.

1. **Neutralization:**
   Acids react with bases to form salt and water, this is called Neutralization.
   $$HCl + NaOH \rightarrow NaCl + H_2O$$

2. **Reaction with metals:**
   Dilute acid reacts with certain metals such as (Zn, Mg and Fe to produce H_2 gas)
   For example: when dilute Hydrochloric acid reacts with Zn metal to produce H_2 gas.
   $$Zn + 2HCl \rightarrow ZnCl_2 + H_2$$

3. **Reaction with carbonate and bicarbonates:**
   Acid react with carbonate and bicarbonate salts to produce CO_2 gas.
   $$Na_2CO_3 + 2HCl \rightarrow 2NaCl + H_2O + CO_2$$

4. **Reaction with oxides and hydroxides of metals:**

Metal oxide and hydroxide react with acid to form salt and water like neutralization.

$$FeO + H_2SO_4 \rightarrow FeSO_4 + H_2O$$

PHYSICAL PROPERTIES OF BASES:

1. Bases have bitter taste.
2. Bases have slippery or soupy touch.
3. They turn red litmus paper blue.
4. They turn colorless phenolphthalein into red or pink.
5. They are good electrolytes that is why the aqueous solution of bases conduct electricity.

DIFFERENT CONCEPTS OF ACIDS AND BASES:

1. ARRHENIUS THEORY:

A Swedish chemist Savant-Arrhenius in 1887 gave the following definition of acids and bases.

"A substance which produce H^+ ions in aqueous its solution is called an acid."

Example:

$$HCl \rightarrow H^+ + Cl^-$$

"A substance which produces Hydroxide (OH^-) ions in its aqueous solution is called base."

Example:

$$NaOH \rightarrow Na^+ + OH^-$$

2. LOWRY AND BRONSTED ACID-BASES THEORY:

This theory was proposed by the English chemist Thomas Lowry and Danish chemist Johannes Bronsted in 1923.

According to which that an acid is a substance having tendency to donate one or more protons and bases is substance, having a tendency to accept protons.

3. LEWIS CONCEPT OF ACIDS AND BASES:

In 1923 G.N.Lewis proposed a more general concept of acids and bases.

According to the Lewis theory:

"An acid is any species (molecule or ion) which can accept a pair of electrons and base is any species which can donate a pair of electrons."

DISSOCIATION OF ACIDS AND BASES:

STRENGTH OF ACID:

Strength of an acid depends on dissociation into ions, higher the power of dissociation greater and vice versa.

STRONG ACID:

The acid which completely ionizes, that means it produces large number of ions (H^+) in aqueous solution, is called strong acid.

Example: HCl, HNO_3, H_2SO_4 and H_3PO_4etc. are the most common examples of strong because they ionize completely in water.

WEAK ACID:

An acid which partially or incompletely ionizes that means it produces very small amount of ions (H^+) inaqueous solution is called weak acid.
Example: H_2CO_3 (carbonic acid) and etc.

STRONG BASE:

A base which completely dissociates into ions that means it produces large number of hydroxyl ions in aqueous solutions is called strong base.
Example: NaOH, KOH, Ca $(OH)_2$ are the best examples of strong bases.

WEAK BASE:

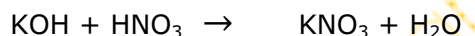
A base which partially or incompletely ionizes into ions, that means it produces very small amount of hydroxyl ions in aqueous solution, is called strong base.

Example: NH_4OH, Mg $(OH)_2$ and Be $(OH)_2$ are few weak bases.

SALT:

"An ionic compound produced as a result of neutralization between acids and bases having positive and negative ions is called salt."

Example: potassium Hydroxide neutralizes Nitric acid to form Potassium Nitrate as salt and water.

$$KOH + HNO_3 \rightarrow KNO_3 + H_2O$$

GROUPS OF SALTS:

On the basis of their chemical nature, salts can be divided into three groups.

1. **Normal salt:**
   A salt which is formed by the incomplete neutralization of an acid by a base is called normal salts, which does not have replaceable ion (H^+) or hydroxyl ion (OH^-).
   Example: NaCl, $NaNO_3$etc. are normal salts.

2. **Acidic salt:**
   A salt which s formed by the partial or incomplete neutralization of an acid by a base is called acidic salt which has replaceable (H^+) ion.
   Example: $NaHSO_4$, $KHCO_3$, $NaHCO_3$etc. are basic salts.

3. **Basic salt:**
   A salt which is formed by the incomplete neutralization of a base by an acid is called basic salt which has hydroxyl ion (OH^-).
   Example: Mg (OH) Cl, Zn (OH) Cl etc. are basic salts.

DOUBLE SALTS:

The crystalline compound which is obtained when two specific salts are crystallized together are known as double salts.

Characteristics of Double Salt:

i. They have definite chemical composition.
ii. They contain definite number of water molecules.

Examples:

Potash Alum
Chrome Alum
Carnalities
Mohr's salt

INDUSTRIAL PREPARATION OF SODIUM CARBONATE (Na_2CO_3)

Now a day's washing soda is commercially prepared by Solvay process or Ammonium soda process.

Raw materials:

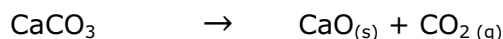
The raw materials are:

i. Lime stone ($CaCO_3$)
ii. Sodium chloride (NaCl)
iii. Ammonium Chloride (NH_4Cl)
iv. Carbon dioxide (CO_2)

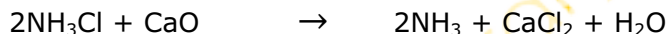
The industrial process involve the following steps:

Step 1:

First of all lime stone ($CaCO_3$) is strongly heated in a special furnace under high temperature.

$$CaCO_3 \rightarrow CaO_{(s)} + CO_{2\ (g)}$$

Step 2:

The quick lime combines with Ammonium Chloride (NH_4Cl) to form Ammonia (NH_3) gas in another chamber

$$2NH_3Cl + CaO \rightarrow 2NH_3 + CaCl_2 + H_2O$$

Step 4:

Ammonium bi carbonate combine with aqueous cold solution of Brine at 15°C to produce Sodium bi carbonate (Baking soda) in the form of insoluble precipitates due to 15°C which is separated out.

Step 5:

Soda ash can be prepared by heating sodium Bicarbonate.

$$2NaHCO_3 \rightarrow Na_2CO_3 + H_2O + CO_2$$

Step 6:

Finally anhydrous Sodium Carbonate (Soda Ash) is crystallized into washing soda ($Na_2CO_3.10H_2O$).

The raw materials like Ammonium Chloride, Carbon dioxide gas and water are reproduced during this process, so the expenses to prepare soda are very much reduced. So this Solvay process is of commercial importance.

USES OF SODIUM CARBONATE:

i. Hard water is changed into soft water by adding solution carbonate (Na_2CO_3). Which forms insoluble Calcium carbonate ($CaCO_3$) and Magnesium Carbonate ($MgCO_3$).
ii. It is used as cleaning agent in soap and detergent.
iii. Ordinary glass is prepared which is used to make bottles.

USES OF BAKING SODA:

i. Sodium Hydrogen Carbonate is used as baking powder.
ii. It is used in the preparation of effervescent drinks and fruit salts.
iii. It is used in medicines to remove acidity in stomach as anti-acid.
iv. It is used in fire extinguishers.

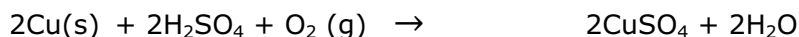
COPPER SULPHATE ($CuSO_45H_2O$):

Preparation:

Copper sulphate or cupric sulphate which is also known as Blue Vitriol or Blue Stone has two preparation methods which are given below:

Method-I:

It may be prepared by reacting copper scraps with dilute Sulphuric acid in the presence of air.

$$2Cu(s) + 2H_2SO_4 + O_2 (g) \rightarrow 2CuSO_4 + 2H_2O$$

Method-II:

It can also be prepared by the treatment of CuO or $CuCO_3$ with dilute sulphuric acid (H_2SO_4)

$$Cu + H_2SO_4 \rightarrow CuSO_4 + H_2O$$

USES OF COPPE SULPHATE:

i. In textile (mordant), tanning, electric batteries, hair dyes and in electroplating.
ii. As germicide, insecticide, preservative for wood, paper pulp.
iii. In calico printing, making synthetic rubber and copper salts e.g. scheels, green paint.
iv. In paint and varnish industry.
v. A mixture of copper sulphate and milk lime is used to kill fungus and molds.

MAGNESIUM SULPHATE ($MgSO_4.7H_2O$) (EPSOM SALT):

Preparation:

It is prepared by the action of H_2SO_4 and magnisite or dolomite, but nowadays it is prepared by heating Kieserite under pressure with water.

i. $MgCO_3 + H_2SO_4 \rightarrow MgSO_4 + H_2O + CO_2$
Magnesite

Uses of Magnesium Sulphate:

i. It is used as mild purgative in medicines.
ii. In dyeing and tanning processes.
iii. In making fire proof fabrics.
iv. As a filler in paper industry

PREPARATION OF POTASH ALUM:

The double salt K_2SO_4. Al $(SO_4)_3$. $24H_2O$ can be prepared by adding equal molecular
Quantities of potassium sulphate and aluminum sulphate by dissolving in water. This solution is crystallized to form Potash Alum.

DISSOCIATION OF WATER:

Water acts as acid as well as a base. A substance like water can behave as both an acid and a base is said to be an amphoteric substance.

In water molecules by adding acid or base water itself ionizes. A proton from one water molecules is transferred to another water molecule leaving behind OH^- ion and forming H_3O^+ ion.

ION PRODUCT OF WATER:

As the result of neutralization salt and water molecules are formed and the concentration of (H^+) ions and Hydroxide ions (OH^-) remain almost same as the following equation shows:

$$H_2O \rightarrow H^+ + OH^-$$

$$K_c = [H^+] [OH^-] / [H_2O]$$

K_c is the equilibrium constant. It shows that a very small fraction of water molecules are ionized. That means water remains mostly unchanged. Therefore,

$$K_c [H_2O] = K_w = [H^+] [OH^-]$$

Equation constant (K_w) is called ion product constant which is the product of molar concentration of (H^+) ion and (OH^-) ion at 25°C is found to be 10^{-14} mole^2/dm^6.

$$[H^+] = 1x10^{-7} \text{ M and } [OH^-] = 1x10^{-7} \text{ M}$$
$$K_w = (1x10^{-7}) \times (1x10^{-7}) = 1x10^{-14}$$

Above equation shows that $[H^+] = [OH^-]$ that is why water is neutral when $[H^+]$ ion concentration increases aqueous solution becomes acidic. If (OH^-) ionic concentration increases aqueous solution becomes basic.

pH SCALE:

The Danish chemist S.P.L Sorenson proposed that only the number in the exponent be used to express the acidity called pH. On this scale a concentration ($1x10^{-7}$) moles of H_2O ions per liter of solution becomes a pH of 7. Similarly a concentration $1x10^{-10}$ M becomes a pH of 10 and so on.

Definition:

The measurement of the negative logarithm of the Hydrogen ion concentration or (H_2O) ion concentration (in moles per liter) is called pH scale.

Mathematically:

$$pH = -\log [H^+]$$
$$= -\log [10^{-7}]$$
$$= -(-7) \log 10$$
$$= 7 \log 10$$
$$= 7 \times 1$$
$$pH = 7$$

Similarly in water p (OH) is negative logarithm of hydroxide ion (OH^-) concentration which is

$$P (OH) = -\log [OH^-]$$

The sum of Ph and Poh of water or any solution is always equal to 14

i.e. Ph + Poh = 14

The Measurement of Ph:

There are following three methods to measure the Ph of a solution.

1. By acid base indicator.
2. By Ph meters.
3. By Ph paper.

Ph paper method is most common in school laboratories. Ph paper strips prepared by treated papers with several different indicators can be used to estimate Ph. These strips are pH papers.

pH can be estimated by dipping the pH paper in a given solution, then by matching the change of color with given key colors with corresponding known values.

The Importance of Ph:

The value of pH in different solutions give information though which necessary steps to control the problems are possible. Water treatment, soil conditioning, swimming pool managements, corrosion control, food processing, electroplating and field of biology etc. are common areas of pH values play important role.

PREPARATION OF SOLUTION OF KNOWN MOLARITY:

Molar solution can be prepared by dissolving one mole of solute into one liter of solution. Consider the example of NaOH 23 + 16 + 1 = 40g sodium hydroxide dissolved in some amount of water in measuring flask etc. after that by adding water up to 1 liter mark, solution of 1M NaOH will be prepared.

STANDARD SOLUTION:

Standard solution is that whose strength or molarity etc. is known.

Example:

1M solution of KOH contain 56g KOH in one liter solution. If half mole 28g KOH is dissolve in one liter solution, this standard solution is called semi molar (0.5M) solution of KOH.

TITRATION:

The volumetric analysis through chemical process in which by using standard solution, the value of concentration of another solution is determined. This method is called Titration.

Acid-Base Titration:

Standard solution of acid is used to standardize base (unknown concentration) by acid base titration or reverse method is possible, to standardize acid.

Steps for carrying out Titration:

Wash all apparatus with water and then rinse the burette with base and pipette with acid including conical flask. Fill the burette with NaOH up to zero mark. The solution in the burette is called Titer.

Pipette out 10ml of HCl in a conical flask and add one or two drops of phenolphthalein indicator. The solution in titration flask is called Titrant.

Add slowly the NaOH solution from the burette into flask with constant shaking until the lightest pink color is obtained. Record the final reading (lower meniscus).

This is called end point. Repeat the process at least three times to get concordant reading (two same difference at least in three readings).

After completing the observation we use the following formula to determine the Molarity of acid or base.

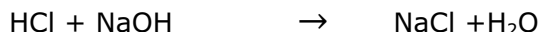
$$M_1V_1/n_1 = M_2V_2/n_2$$

Let M_1 = Molarity of Acid.
V_1 = Volume of Acid.
N_1 = No. o moles of acid (obtained from balanced equation)
N_2 = No. of moles of base (obtained from base)
V_2 = Volume of base (Burette reading)
M_2 = Molarity of base

NEUTRALIZATION:

The process in which equivalent quantities of an acid and base are reacted to form, salt and water is called neutralization reaction.

A common example is the reaction between HCl and NaOH.

$$HCl + NaOH \rightarrow NaCl + H_2O$$

The hydrogen on which is responsible for acidic properties, reacts with the Hydroxide ion which is responsible for the basic properties, producing neutral water (H-OH). Because the only change that takes place is the reaction of the hydrogen ion and hydroxide ion, the neutralization may be expressed simply as:

$$H^+ + OH^- \rightarrow H_2O$$

The neutralization is an exothermic reaction.

MONO AND POLY ACIDS AND BASES:
MONO BASIC AND POLY BASIC ACIDS:
Basicity of Acids:

The number of replaceable or ionizable Hydrogen atoms present in a molecule of an acid is called Basicity of the acid.

An acid yields protons. Different acids have different number of protons (acidic-hydrogen) per molecule and yield different number of H_3O^+ ion in a solution.

The common acids like HCl, HNO_3 and CH_3COOH contain only one acidic Hydrogen atom per molecule, when dissolved in water 1 mole of each of these acids is capable of producing 1 mole of hydrated $H^+ = H_3O^+$ ions and in order to neutralize this solution 1 mole of (OH^-) ions is required. Consequently these acids are called mono-basic acids more commonly called mono-protic acids

$$H - Cl + H - OH \rightarrow H_2O + Cl$$

MONO-ACID AND POLY-ACID BASES:
Acidity of Bases:

The number of ionizable or replaceable (OH^-) ions, present in a molecule of base is called acidity of the base.

Similarly, bases that produce 1 mole of (OH^-) ions per mole of base (such as NaOH and KOH) are called mono-acid bases. Bases that produce 2 moles of (OH^-) ions per one mole of base (such as $Ca(OH)_2$ AND $Ba(OH)_2$) are called di-acid bases and bases that produce 3 moles of (OH^-) ions per 1 mole of base (such as $Al(OH)_3$) and $Cr(OH)_3$ are called tri-acid bases.

Bases that contain two, three or more hydroxide (OH^-) ions per molecule are called poly-acid bases.

DISSOCIATION OF ACIDS AND BASES:
ACID STRENGTH AND BASE STRENGTH:
Definition:

A strong acid is one, that is almost completely dissociated (strong electrolytes) i.e. an acid that produce large number of (H^+) ions in aqueous solution is said to be a strong acid. Typical examples of strong acids are hydrochloric acid (HCl), Nitric acid and sulphuric acid.

Different acids differ in their ability to donate protons.

Weak Acid:

A weak acid is one, that is only partially dissociated (weak electrolytes).
Only small fraction of the weak acids transfer a proton to water. Typical examples of weak acids are nitrous acid. Phosphoric acid etc.

Strong base:

The strong base is one. That is almost dissociated completely (strong electrolytes). That is, a base which yield large number of (OH^-) ions in aqueous solution, is said to be a strong base.

Most metal hydroxides, such as NaOH and KOH are strong electrolytes and strong bases.

Weak Base:

A weak base is one, that is only partially dissociated weak electrolytes; weak bases dissociate to a small extent in water to yield (OH^-) ions.

Typical examples of weak bases are NH_4OH, $Mg(OH)_2$ and etc. hence, the relative strength of weak bases may be measured by the extent to which the dissociate in water to yield Hydroxide ions (OH^-)

EXERCISE

1. FILL IN THE BLANKS.
   i. The formula of baking soda is **$NaHCO_3$**.
   ii. The formula of Epsom salt is **$MgSO_4.7H_2O$.**
   iii. $K_2SO_4AL_2.24H_2O$ is the formula of **Potash Alum.**
   iv. **Molarity** is the most convenient way of expressing concentration.
   v. The molarity of solution is denoted by **M.**
   vi. A solution whose strength is known is called **Standard Solution**.
   vii. Molarity is defined as number of moles per **liter or dm^3 of solution**

CHEMICAL ENERGETICS

INTRODUCTION

The chemical reactions during which material changes are accompanied with change in heat energy are called thermo chemical reactions. The branch of chemistry which deals with the study of heat changes in chemical reactions is called thermo chemistry. There are two types of thermo chemical reactions i.e. exothermic and endothermic chemical reactions.

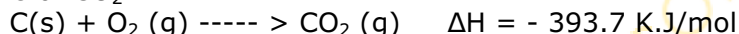
10.1 EXOTHERMIC AND ENDOTHERMIC REACTIONS

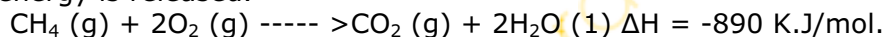
10.1.1 Exothermic Reaction:

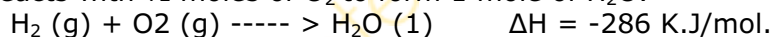
It is Greek word and composed of EXO means out of or to evolve + THERME means heat. An exothermic reaction is the chemical change during which heat is given out or released. The change of heat is represented by AH and it is shown by negative, sign.

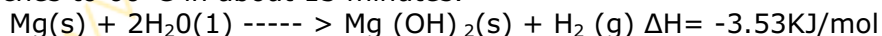
Examples:

(i) The combustion of coal in air is the example of exothermic reaction. 393.7 Kilo joules of heat energy is released when 1 mole of coal is burnt in 1 mole of O_2 to produce 1 mole of CO_2.

$$C(s) + O_2 (g) \text{ ----- } > CO_2 (g) \quad \Delta H = - 393.7 \text{ K.J/mol}$$

Burning of methane in presence of oxygen is another example of exothermic reaction. When 1 mole of methane is burnt in 2 moles of O_2 then 1 mole of CO_2 and 2 moles of water are formed. During these reaction 890 Kilo joules per mole of heat energy is released.

$$CH_4 (g) + 2O_2 (g) \text{ ----- } >CO_2 (g) + 2H_2O (1) \ \Delta H = -890 \text{ K.J/mol.}$$

(iii) The formation of water from hydrogen and oxygen is also example of exothermic reaction 286 Kilo joules per mole of heat energy is released, when 1 mole of H_2 reacts with ½ moles of O_2 to form 1 mole of H_2O.

$$H_2 (g) + O2 (g) \text{ ----- } > H_2O (1) \quad \Delta H = -286 \text{ K.J/mol.}$$

Generally in exothermic reactions, heat flows from the system to surroundings and container becomes hot, this is only possible, when total energy of the reactants is greater than total energy of products. The difference in the energies is the heat supplied by the system to surroundings. Using Exothermic Reactions to Warm Food: In modern army, food rations can be warmed without benefit of stove or campfire. The pouch that contains the food is attached to flameless radiation heater. The heater contains chemicals that react with water to produce heat. When the pouch is placed in a bag and water added, temperature of the food reaches to 60°C in about 15 minutes.

$$Mg(s) + 2H_20(1) \text{ ----- } > Mg (OH)_2(s) + H_2 (g) \ \Delta H= -3.53KJ/mol$$

The reaction of (Mg) with water is slow, because of the formation of film oxide (MgO). The reaction of Mg with water is highly accelerated in the presence of iron (Fe) and ordinary salt (NaCl). Thus, the flameless radiation heater contains a mixture of Mg, Fe and NaCl.

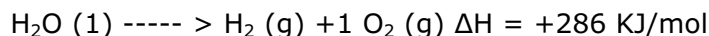
10.1.2 Endothermic Reactions:

It is Greek word and composed of ENDO mean into or to absorb and THERME means heat. Endothermic reaction is the chemical change during which heat is absorbed or taken in. The change of heat energy is represented by Δ H and sign of A H is positive (+Δ H= Absorbs heat). During the endothermic reaction heat is absorbed from the surroundings, it means heat flows from surroundings to the system and container becomes cold. This is because the total energy of the products is greater than the total energy of reactants. Here, the difference in the energies is the heat supplied to the system by the surroundings.

Examples:

(i) The decomposition of water into hydrogen and oxygen is example of endothermic reaction. During decomposition of 1 mole of water to 1 mole of

hydrogen and half mole of oxygen 286 Kilo joules per mole of heat energy is absorbed.

$$H_2O\ (1)\ \text{-----} > H_2\ (g) + 1\ O_2\ (g)\ \Delta H = +286\ KJ/mol$$

(ii) 1 mole of nitric oxide (NO) is formed by combination of ½ mole of N_2 and ½ mole of O_2 .This is the example of endothermic reaction and heat absorbed is about 90.25 Kilo joules per mole.

$$\frac{1}{2} N_2\ (g) + \frac{1}{2} O2\ (g)\ \text{-----} > NO\ (g)\quad \Delta H = +\ 90.25\ KJ/mol$$

10.2 HEAT CONTENTS OP REACTION

Every substance possesses a characteristic internal energy and internal energy depends upon the structure and physical state of that substance. The energy possessed by a substance is called heat contents of that substance. During a chemical reaction, the reactants are converted into products and heat energy is either absorbed or evolved. This is because the heat contents of these respective substances are different. The heat evolved or absorbed at constant pressure is called as enthalpy of the reaction.

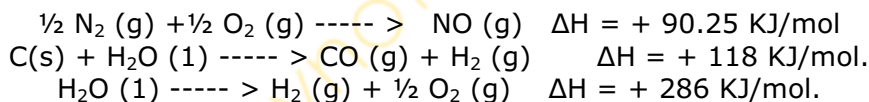
The heat content (enthalpy) of a substance is represented by "H" and the change in heat content during a chemical reaction is then represented by ΔH. Here Greek letter Δ (delta) signifying the change in the property. It means the change in heat content during chemical reaction is the difference between the heat content of products and reactants of that reaction.

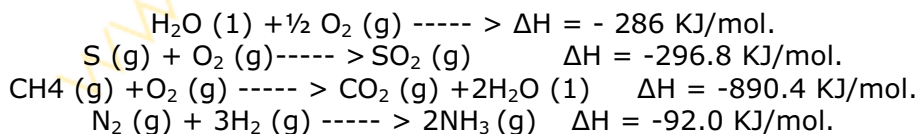
It is difficult to measure the enthalpy of a reaction, but we can measure the change in enthalpy which is denoted by (ΔH). It is obtained by subtracting the enthalpy of reactant (HJ from enthalpy of products (H2).

$$\Delta H \quad = \quad (H_2 \quad - \quad H_1)$$

Change of Enthalpy   Heat content of product   Heat content of reactions

If enthalpy of products is greater than the enthalpy of reactants, then the sign of A H will be positive and over all reaction is endothermic and heat is absorbed.

$$\frac{1}{2} N_2\ (g) + \frac{1}{2} O_2\ (g)\ \text{-----} > NO\ (g)\quad \Delta H = +\ 90.25\ KJ/mol$$
$$C(s) + H_2O\ (1)\ \text{-----} > CO\ (g) + H_2\ (g)\quad \Delta H = +\ 118\ KJ/mol.$$
$$H_2O\ (1)\ \text{-----} > H_2\ (g) + \frac{1}{2} O_2\ (g)\quad \Delta H = +\ 286\ KJ/mol.$$

If enthalpy of product is smaller than the reactants, then the sign of ΔH will be negative and overall reaction is exothermic and heat is evolved. The examples of exothermic reactions are following:

$$H_2O\ (1) + \frac{1}{2} O_2\ (g)\ \text{-----} > \Delta H = -\ 286\ KJ/mol.$$
$$S\ (g) + O_2\ (g)\text{-----} > SO_2\ (g)\quad \Delta H = -296.8\ KJ/mol.$$
$$CH4\ (g) + O_2\ (g)\ \text{-----} > CO_2\ (g) + 2H_2O\ (1)\quad \Delta H = -890.4\ KJ/mol.$$
$$N_2\ (g) + 3H_2\ (g)\ \text{-----} > 2NH_3\ (g)\quad \Delta H = -92.0\ KJ/mol.$$

10.3 MEASUREMENT OF HEAT OF REACTION

The heat absorbed or evolved during thermo chemical reaction is called heat of reaction. Exothermic and endothermic reactions can easily be detected by touching the vessel before and after chemical reaction. The increases in temperature indicate that reaction is exothermic and decrease in temperature indicates that the reaction is endothermic. The accurate values of ΔH can be determined by using calorimeter. The simple type of calorimeter is an insulated container fitted with thermometer and a stirrer. Known amounts of reactants are placed in calorimeter, when reaction proceeds the heat energy evolved or absorbed will either cool or warm the system. ΔH for reaction may be calculated by determining the difference in temperature, mass of reactants and specific heat of reaction mixture.

Heat of Neutralization:

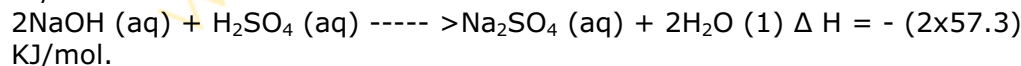
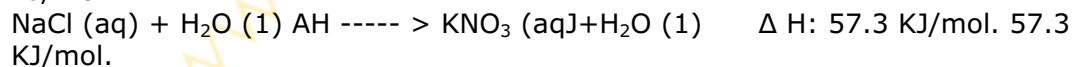
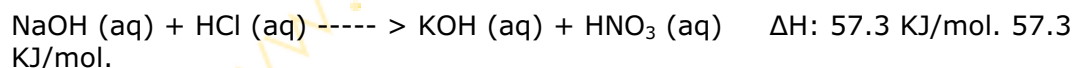
The reaction between an acid and base to form a salt and water is called neutralization reaction. Neutralization reaction is an example of exothermic reaction. The amount of heat released during a neutralization reaction in which 1 mole of water is formed is called as the heat of neutralization or the amount of heat released when 1 mole of hydrogen ions (H^+) from an acid reacts with 1 mole of hydroxide ions (OH^-) from base to form salt and one mole of water is called heat of neutralization. Procedure:
Take 50 cm^3 of molar NaOH solution and note its temperature (t^1) and 50 cm^3 of molar HCl solution and note its temperature (t^2). The two temperatures will be usually same, but they need not. Pour the HCl solution in 250 mls breaker (Calorimeter) and then add quickly NaOH solution the solution being stirred all the time, and note down the highest temperature reached during the reaction. At the end weigh the calorimeter with salt solution. Heat of neutralization is calculated by the following formula.
$\Delta H = m \times S \times (t2 - t1)$ or $\Delta H = m \times S \times \Delta t$

Observation and Calculations

(1) Mass of calorimeter along with stirrer = w_1 = 50g
(2) Mass of calorimeter along with stirrer + salt sol. = w2 = 150g
(3) Mass of salt solution (w1 – w2) = m = 100g
(4) Specific heat of salt solution = s = 4.25J/g/^{o}C
(5) Initial temperature of reactants t1 = t2 = t^{o}C = 20^{o}C
(6) Final highest temperature = t_3^{o}C = 20^{o}C
(7) Increase in temperature i.e. t3^{o}C - t° = Δt = 6.8^{o}C

Then
Heat of neutralization is given by Δ H = ms Δ t
$\Delta H = 100g \times 4.25J/1g \times 1^{O}C \times 6.8^{O}C = 2856J$

The value obtained i.e. 2856J is for 50 mls of solution, it must be multiplied by 20 to give the amount of heat evolved, when 1 mole of NaOH is neutralized by HQ
2856 J x 20 = 57120 J = 57.12 K.J/mol
Result: The heat of neutralization of NaOH by HC1 is ΔH = -57.12 KJ/mol.
Note: The heat of neutralization for any strong acid with strong base is approximately same.
For example:

NaOH (aq) + HCl (aq) ----- > KOH (aq) + HNO_3 (aq) ΔH: 57.3 KJ/mol. 57.3 KJ/mol.
NaCl (aq) + H_2O (1) AH ----- > KNO_3 (aqJ+H_2O (1) Δ H: 57.3 KJ/mol. 57.3 KJ/mol.
2NaOH (aq) + H_2SO_4 (aq) ----- >Na_2SO_4 (aq) + 2H_2O (1) Δ H = - (2x57.3) KJ/mol.

SUMMARY

Heat energy is given out in exothermic reaction.
Heat energy is absorbed in endothermic reaction.
In chemical reactions, the material change is accompanied with the change of heat energy.
There are two types of thermochemical reactions i.e. exothermic and endothermic reaction.
All combustion reactions are the examples of exothermic reactions. The enthalpy is represented by "H" and change of enthalpy is represented by " Δ H”
The energy given out or absorbed at constant pressure is called enthalpy of the reaction.
Another name for heat content of a reaction is enthalpy of the reaction. In neutralization reactions, the heat is evolved, which is called as heat of neutralization.

The change in heat contents during a chemical reaction is the difference between the heat content of products and reactants.
When enthalpy of products is greater than the enthalpy of reactants than the reaction will be endothermic.
The sign of ΔH for exothermic reactions is negative ($^-$ve)
The sign ΔH for endothermic reaction is positive. ($^+$ve)

EXERCISE

Fill in the blanks:
(i) The heat given out in a chemical reaction is called ______ reaction.
(ii) In ______ reaction, heat is taken in.
(iii) Heat evolved or absorbed during chemical reaction at constant pressure is called ______
(iv) Acid base reaction is called ______ reaction.
(v) C(s) + O_2 (g) ----- > CO_2 (g) Δ H = ______ KJ/mol,
(vi) H_2 (g) + J- 08(g) ----- >H_2O (1) Δ H = ______ KJ/mol.

Tick the correct answers:
(i) In an exothermic reaction.
(a) Heat energy is lost. (b) Heat energy is gained.
(c) Heat energy is lost as well as gained.
(d) None of them.
(ii) In an exothermic reaction.
(a) Container becomes hot.
(b) Container becomes cold.
(c) The temperature of container remains the same.
(d) None of them.
(iii) During an endothermic reaction.
(a) Container used becomes cold.
(b) Container used becomes hot.
(c) The temperature of container used remains same.
(d) Total energy of reactants increases.
(iv) The heat evolved during the formation of 1 mole of water from H_2 and O_2 is
(a) 286 Kilo joules/mol (c) 300 Kilo joules/mol
(b) 186 Kilo joules/mol (d) 200 Kilo joules/mol
(v) The formation of water from H_2 and O_2 is example
(a) Exothermic reaction. (b) Endothermic reaction
(c) Neutralization reaction, (d) None of them.

Write answer of the following questions:

Define the following terms:
(a)Thermo chemistry, (b) Endothermic reaction
(c) Exothermic reaction.
(ii)Give at least two examples of exothermic reactions and two examples of endothermic reactions.
(iii)Which of the following are exothermic or endothermic processes?
(a) The decomposition of mercuric oxide (HgO)
(b) The electrolysis of water.
(c)The reaction of (Na) with water.
(d) The burning of methane CH_4.
(e) The decomposition of $KClO_3$.
(f) A match burn. Define the following terms:
(a) Enthalpy. (b) Enthalpy of reaction.
Define heat of neutralization,. What would be the value of heat of neutralization, when strong acid reacts with strong base?